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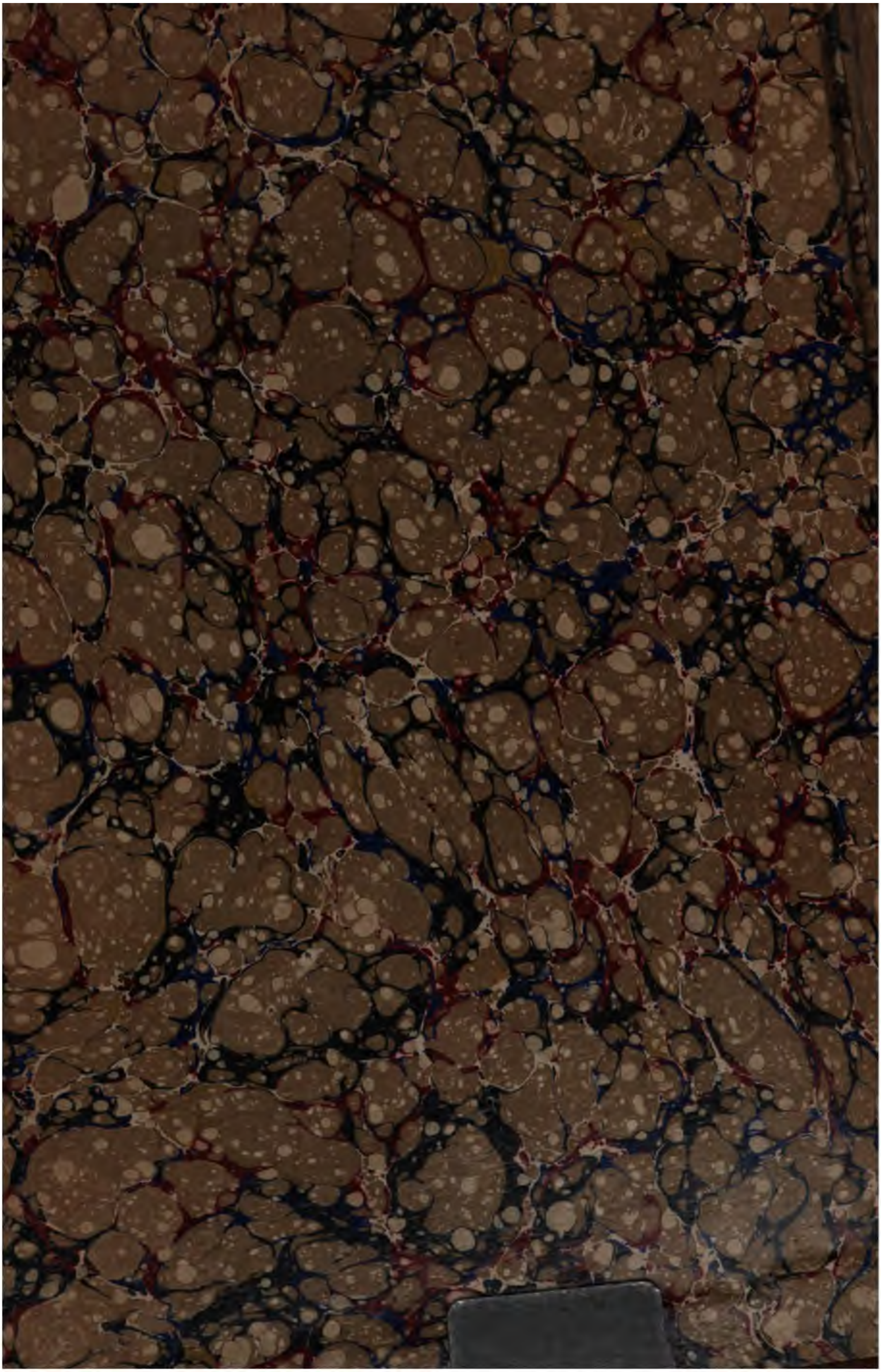

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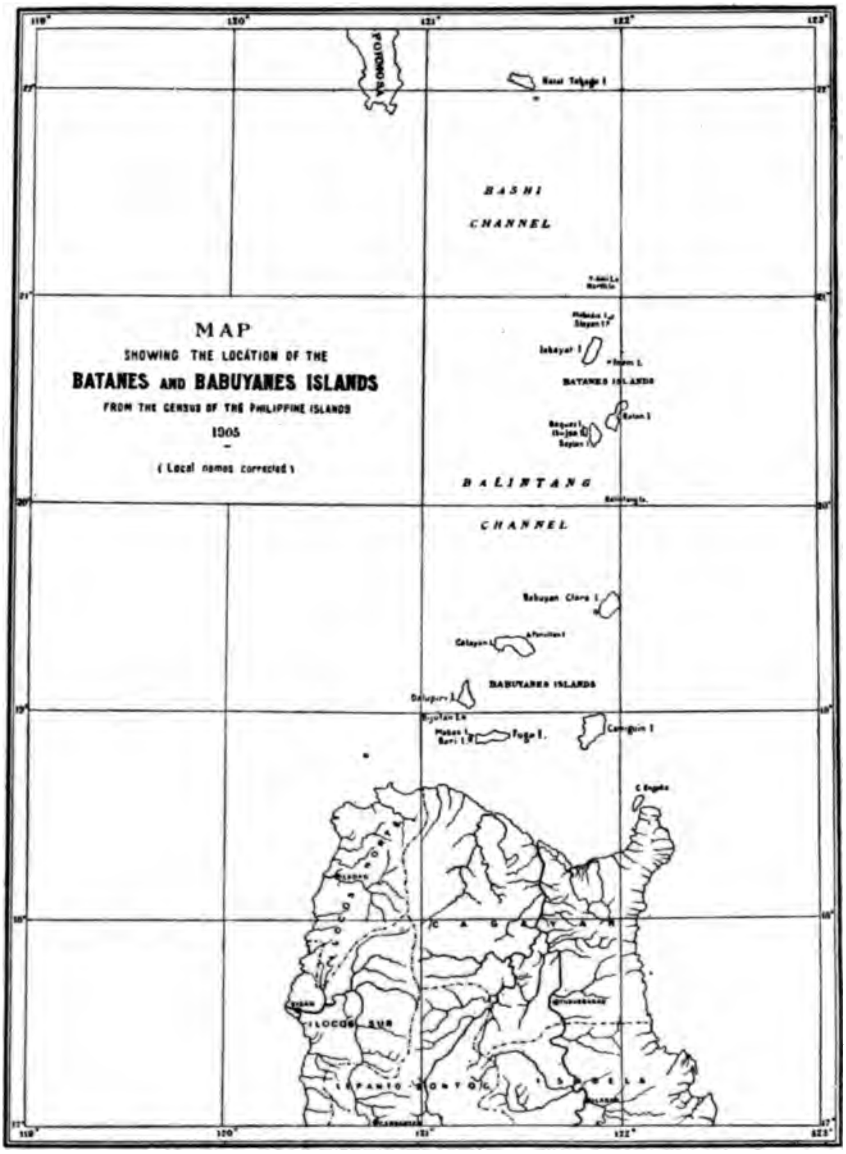
MAP
SHOWING THE LOCATION OF THE
BATANES AND BABUYANES ISLANDS
FROM THE CENSUS OF THE PHILIPPINE ISLANDS
1905
(Local names corrected)
119°
120°
121°
122°
123°
22°
21°
20°
19°
18°
17°
FORMOSA
BASHI
CHANNEL
Itbayat I.
BATANES ISLANDS
Batan I.
Sabtan I.
BALINTANG
CHANNEL
Babuyan Claro I.
Calayan I.
BABUYANES ISLANDS
Dalupiri I.
Fuga I.
Camiguin I.
CAGAYAN
ILOCOS NORTE
ILOCOS SUR
LEPANTO-BONTOC
ISABELA

Map No. 1.

THE PHILIPPINE

JOURNAL OF SCIENCE

A. GENERAL SCIENCE

VOL. III FEBRUARY, 1908 No. 1

CONTRIBUTIONS TO THE PHYSIOGRAPHY OF THE PHILIPPINE ISLANDS: II. THE BATANES ISLANDS.[1]

By HENRY G. FERGUSON.
(From the Division of Mines, Bureau of Science, Manila, P. I.)

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LOCATION.
PEOPLE.
HISTORY.
CLIMATE.
GEOGRAPHICAL DESCRIPTION.
    Sabtan.
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    Inem.
    The Siayanes.
    Ibujos.
    Desquey.
    Isbayat.
SUBMARINE CONFIGURATION.
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    Origin of the agglomerate.
    Faulting.
    Alignment of volcanoes.
    Correlation with Formosa and the Babuyanes.

---

[1] The first paper of this series, Cebu Island, by Warren D. Smith, was published in *This Journal* (1906), 1, 1043.

PHYSIOGRAPHY.
- Formation of the land.
- The Sabtan Upland.
- Period of Uplift and Erosion.
- Sinking of Ibujos and Desquey.
- Possible Recent Depression.
- Marine Erosion.
- Tidal scour.
- Coral.
- Vulcanism.
- Human response and physiographic conditions.
- Summary.

INTRODUCTION.

This paper, embodying results of work during three weeks spent in geologic reconnaissance in the Batanes Islands, is intended to be preliminary to an article which will deal more fully with the geology and petrography of this group; hence the problems of structural geology will be in the main reserved for the later discussion and I shall here confine myself principally to the physiography.

Before proceeding to a description of this group, I wish to acknowledge my indebtedness to Major-General Leonard Wood, commanding general, Philippines Division, to Commissioner Dean C. Worcester, to Mr. William Edmonds, supervising teacher of the Batanes Islands, for his unfailing hospitality and for much helpful information, and to the native teachers and boys of his schools, particularly Mr. Jose Aguedo, for their freely rendered services as guides during my stay in the islands.

LOCATION.

The Batanes Islands form the most northern portion of Philippine territory and consist of the islands of Y'Ami, Maysanga,[2] Mabudis, Siayan, Isbayat, Inem, Batan, Sabtan, Ibujos and Desquey, of which Isbayat, Batan, Sabtan and Ibujos are inhabited. They lie between latitude 20° 16′ and 21° 05′ north (21° 13′ north if the *"existence doubtful"* Bashi rocks are included), or approximately the latitude of the southern half of the Hawaiian Islands, and between longitude 121° 49′ and 122° 02′ east. Y'Ami, the most northern island, is about 270 kilometers from Cape Engaño, the nearest point of Luzon, 107 kilometers from the Japanese island of Little Botel Tobago and 160 kilometers from the southern point of Formosa. It is said that on a very clear day the Formosan mountains can be seen from the summit of Mount Iraya in Batan Island. The Bashi Channel with a minimum depth of 1,009 fathoms separates the islands from Formosa and the Botel Tobagos to the north, while on the south the Balingtang Channel (depth of 95 fathoms without bottom) lies between them and the Babuyanes. The Balingtang Islands, lone rocks rising perpendicularly from the sea, lie in the center of the Balingtang Channel and form a connecting link between the Batanes and the Babuyanes groups.

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[2] Where the local name differs from that given on the United States Coast and Geodetic Survey chart, I have followed the local usage. This chart, based on a British survey made in 1845, is badly confused as to local names, and is unreliable in regard to details of topography. On the maps reproduced in this paper the names are corrected to conform to local usage.

PEOPLE.

The Batanes people form a separate race, speaking their own language, or languages, for that of Isbayat is different from the language of the other islands. Professor Scheerer[3] considers the inhabitants of Batan and Sabtan to be of Malay stock, while those of Isbayat are mixed Malayan and Papuan. They are kindly, intelligent, enterprising and extremely industrious. Throughout the Babuyanes and northern Luzon the Batanes people have the reputation for being excellent workers. The two principal islands, Batan and Sabtan, are overpopulated and the arable land is largely taken up, hence there has been considerable emigration and one finds people from the Batanes scattered throughout the Babuyanes Islands and Luzon.

In the days before the Spanish occupation, the constant warfare between the villages made purposes of defense the first requisite in the choice of a village site, hence the inhabitants lived on the hilltops, going down to work in the fields by day, after the manner of the Pueblo Indians of America. The ruins of these old towns are to be seen on the hills above San Vicente (Batan) and Itbod. Itbod was extremely elaborate, being built more in the form of a single fort than a village. Remains of a large cistern and of storehouses show that the inhabitants were prepared to resist a siege, and ruins of small buildings, apparently watchtowers overlooking the cultivated patches, show the precautions which were taken against surprise. It was here that the natives made their only stand against the Spaniards, being overcome by cannon planted on a neighboring hill.

With the coming of the Spaniards the hill towns were destroyed and the people forced to move into seacoast villages, the sites of which were as a rule dependent upon the presence of gaps in the coral reefs.

HISTORY.

The group was discovered by William Dampier in 1687 and named by him the Bashi Islands, after an intoxicating drink brewed from sugar cane (now however termed *palic* by the islanders). Later in the same year three Dominican missionaries visited the Batanes, but after the death of two of them, the survivor returned to Luzon. In 1724 four Dominicans arrived and stayed for a short time, but it was not until 1791 that the Spanish régime was fully established. From September,

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[3] Scheerer, Otto: *Mitt. der Deutsch. Gesellschft. f. Natur und Völkerkunde Ostasiens*, Tokyo (1906), 11, Pt. I.

1897, to December, 1899, the islands were under the control of the revolutionary government.[4]

The present name *Batanes* has been used on Spanish maps since the Spanish occupation, but until a few years ago the original name of Bashi Islands was used on American maps, as it is on the English and German of to-day. Professor Scheerer[5] considers two groups; the Bashi Group which consists of Isbayat and the small northern islands, and the Batanes which are composed of Batan, Sabtan, Ibujos, and Desquey. Professor Kôtô, in his articles on the Malayan Archipelago and the dependent isles of Taiwan, makes the same division.[6]

CLIMATE.[7]

Rainfall.—The records of the Weather Bureau covering Santo Domingo de Basco for the years 1903–1906 are given in Table 1. These show a very heavy annual rainfall, the tenth heaviest recorded and no very marked rainy season such as is found on the west coast of Luzon, where the records of Vigan (Ilocos Sur) show that 92.9 per cent of an average annual rainfall of 2,134.1 millimeters occurs during the rainy season from June to October. The seasons in the Batanes may best be defined as a short, dry season from February to May and a long, rainy one. Extreme differences of monthly rainfall such as those between May, 1905 and 1906, are due to typhoons. In May, 1906, two typhoons passed near the islands causing a precipitation of 153.8 millimeters on the 18th and 19th of the month and 390.8 on the 28th, 29th and 30th.

TABLE I.—*Monthly rainfall at Santo Domingo de Basco for the years 1903 to 1906, inclusive.*

Month.	Millimeters of rainfall in—				
	1903.	1904.	1905.	1906.	Mean.
January	270.1	306.8	150.2	327.6	163.7
February	27.2	66.7	85.5	12.5	48.0
March	51.8	20.0	154.8	119.9	86.6
April	141.0	10.2	89.0	207.5	111.9
May	201.1	110.8	21.0	677.0	252.4
June	163.6	262.7	151.0	90.1	166.8
July	340.7	406.5	267.6	202.0	304.2
August	910.7	377.0	207.6	127.4	405.7
September	186.9	168.6	186.1	424.1	241.4
October	734.1	151.3	370.8	618.6	468.7
November	310.8	121.2	123.0	190.8	186.4
December	344.3	363.5	227.6	361.9	324.3
Total	3,682.3	2,364.8	2,034.2	3,359.4	2,860.1

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[4] From historical note contributed by William Edmonds to Philippine History, vol. 44.

[5] *Loc. cit.*

[6] Kôtô, B.: *Jour. Coll. Sci.* Tokyo (1899), **11**, II. 118 and (1900), **13**, I. 46.

[7] Statistics from Monthly Bulletins of the Weather Bureau for 1904, 1905, 1906, and Maso, Rev. M. Saderra, S. J.: The Rainfall in the Philippines, Manila (1907), Weather Bureau.

Typhoons.—The islands lie in the track of numerous typhoons which often completely destroy the crops and reduce the inhabitants to the verge of starvation. The houses are all built of stone for protection against these winds and at the times of typhoons, nets are stretched across the roofs and anchored to the ground. Typhoons of the first, third, and fifth groups, amounting to 63 per cent of the total number, affect the Batanes Islands.[8]

Temperature.—Table II gives the mean monthly temperatures for Santo Domingo de Basco compared with that of Manila for the years 1904 and 1906. It will be seen while there is very little difference in the mean temperature, the range is much greater in the Batanes than in Manila, being over 6° for the former and less than 4° for the latter.

TABLE II.—*Mean monthly temperatures in Santo Domingo de Basco and in Manila for the years 1904 and 1906.*

Month.	1904.		1906.	
	Santo Domingo de Basco.	Manila.	Santo Domingo de Basco.	Manila.
January	21.4	25.1	22.7	25.1
February	21.5	25.4	24.0	26.1
March	23.6	26.2	23.8	26.8
April	26.0	26.9	26.5	29.2
May	27.3	27.8	27.8	28.7
June	27.3	27.2	28.4	28.0
July	27.0	26.7	28.7	27.8
August	27.7	26.8	28.8	27.3
September	27.2	26.2	28.0	26.7
October	26.4	26.3	25.9	26.4
November	24.0	25.0	24.5	25.3
December	21.8	23.9	23	25.0
Mean	25.1	26.1	26	26.9

GEOGRAPHICAL DESCRIPTION.

The geologic structure upon which the topography of the islands is largely dependent naturally brings the Batanes into three groups:

1. The islands consisting in greater part of the older rocks, volcanic agglomerate with basic dikes. To this group belong the Island of Sabtan and southern part of Batan.
2. The younger volcanic group, consisting of Mount Iraya in Batan, the Island of Inem and the small islands to the north of Isbayat, locally known as the Siayanes.
3. The coral limestone group, Desquey, Ibujos and most probably Isbayat.

---

[8] **Algue, Rev. Jose, J. S.:** The Cyclones of the Far East, Manila (1904), 247.

SABTAN.

The Island of Sabtan is the southernmost of the Batanes Group. It is about 10 kilometers long by 4 broad and contains five villages, San Vicente, Santo Tomás and Santa Rosa on the east coast, Santa Inés and San Luis on the western side. From Point Natao southward on the east coast to within half a mile of Santa Rosa, there is no marked relief along the shore, with the exception of some high bluffs of volcanic agglomerate just south of San Vicente. Coral reefs extend over a large part of the coast, although their development here is not as extensive as on the west coast. South of Santo Tomas there is a long, flat stretch near the shore and here sand dunes reaching to a height of about 100 feet have dammed back the waters from the interior, forming a line of small ponds.

The land from the eastern shore rises toward the center of the island in a rather irregular series of marine terraces. The materials forming these terraces are stratified pebbles and sand, for the most part entirely unconsolidated, together with limestone, the latter both limestone conglomerate and coral limestone. These terraces when viewed from the neighboring island, Batan, seem to be beautifully regular, but on closer examination they are seen to be absolutely without continuity, probably due to the fact that where the protecting capping of limestone is absent, the terrace of pebbles and sand is soon worn away. The highest ledge of limestone occurs at an elevation of about 180 meters. It is a quarter of a mile inland and contains poorly preserved *Orbitoides*. Beyond the last terrace, the country is very deeply dissected and consists of irregular, sharp ridges of volcanic agglomerate, generally much decomposed.

A belt of rolling upland between a half mile and a mile wide extends diagonally across the island from Santa Rosa to Santa Inés. This has an average elevation of about 300 meters; it is bounded on the east by a sharp and very irregular escarpment of volcanic agglomerate. The valleys in this upland are broad and the small streams seem to be at grade, the topography being best described as "gently rolling," in marked contrast to the sharp feature of the irregular ridges below, in general it is a region of physiographic "old age." This upland rises gradually to the westward, the pass a half mile northeast of San Luis having an elevation of 400 meters, and it ends in a sharp line of cliffs broken only by occasional steep canyons. These cliffs extend along the whole west coast of the island, being lower (200 meters) towards Natao Point. The material is almost entirely volcanic agglomerate, with occasional beds of stratified sandstone and conglomerate which consist entirely of volcanic material. This rock where it occurs is much faulted, the faults being of small throw, generally less than 10 feet, and also somewhat distorted, showing small dips to the west and northwest. Of course, the folding and faulting are not confined to those parts of the agglomerate formation in which the sandstone occurs, but it is only where there are bedded deposits that distortion is readily distinguishable.

Between Santa Inés and San Luis at an elevation of about 7 meters, there is a raised beach consisting of pebbles and a limestone conglomerate which also contains many volcanic pebbles. This beach is of so recent a date that the streams from the plateau have not yet had time to cut channels through it. From Natao Point, southward to Tangel Point, there extends an unbroken coral reef of considerable width. At the bay just north of Tangel is a flat, triangular stretch of marshy land formed by the ponding back of a small stream by the beach. Here there was a village until recent years, but because of its unhealthy situation it was abandoned and the land given over to cultivation, being almost the only piece of cultivated land on the west coast of Sabtan.

The southern portion of Sabtan is extremely rugged. It consists of sharp, irregular ridges of agglomerate ending in steep cliffs. The western part is impassible by land and at the time of my visit the sea was too rough to attempt the trip by boat. On the east coast I was able to travel as far south as Point Ajao. Here, steep cliffs of agglomerate, often cut by large dikes of hornblende and augite porphyry (f. n.) jut into the sea. No raised beaches or limestone were seen, but for about 8 meters above sea level the rocks were pitted as if by the borings of marine animals. The ridges of agglomerate seem to run in a general southeasterly direction, meeting the shore *en echelon* and forming a series of small points. The principal ridge, Ceskid Mountain, ending in Ajao Point, shows a remarkably serrate skyline.

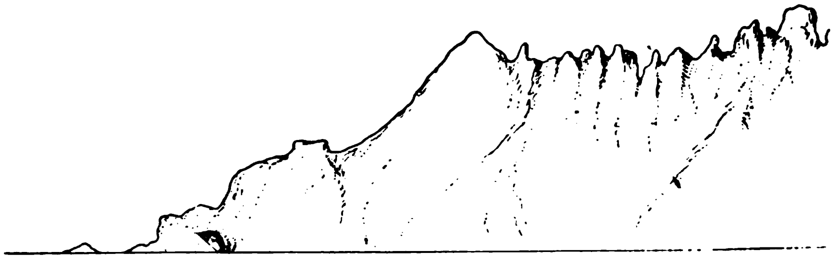

FIG. 1. CESKID MOUNTAIN AND AJAO POINT.

BATAN.

Batan Island is about 20 kilometers long, lies in a northeasterly southwesterly direction and varies from less than 2 kilometers to nearly 6 in width. The topography of the island falls into two distinct parts—first, the extreme northern end, northward from Santo Domingo, which is dependent on Iraya Volcano, and second the southern and by far the larger portion, which shows an independent topography which in many respects is similar to that of the Island of Sabtan. Aside from Mount Iraya, the principal topographic feature is a range of hills extending diagonally across the island from Mabatuy Point on the west coast to Desiay Point, the southeastern corner of the island. This ridge rises abruptly from the sea at Mabatuy Point and extends southeast for about 2 kilometers where it reaches its highest elevation of about 460 meters at the twin peaks of Mount Matarem, thence it runs nearly south for a little over a kilometer, then turns southeast again, and where the Itbod gorge cuts through the ridge its direction is nearly east. (See Pls. II and III.)

Various spurs run off from the main ridge in all directions, and the topography is extremely confusing. A prominent ridge, with minor subsidiary ones, runs eastward from Chaua Point across the island. Another ridge extends eastward from Mount Matarem, the latter forming, with the main southeasterly ridge a large amphitheatral valley drained by the streams flowing through the Itbod gorges. The material of these ridges is all volcanic agglomerate, with occasional outcrops of igneous rock and scattered areas of stratified sandstone and conglomerate. The agglomerate ridges are sharp and ragged in their upper portions and are cut by streams in deep box cañons. The lower parts and the smaller spurs are covered by a thick mantle of decomposed material, generally in the form of a red clay with partly decomposed volcanic pebbles. The gradual downward creeping of this material on the hillside has given a rough stratification parallel to the contour of the hill. The agglomerate ridges form steep cliffs when they reach the sea as they do at Chaua and Mabatuy Points at the coast northwest from Itbod, and along the east coast of the island south from Eskid Bay (north of Mananioy). Where they are fissured, deep sea-caves are produced.

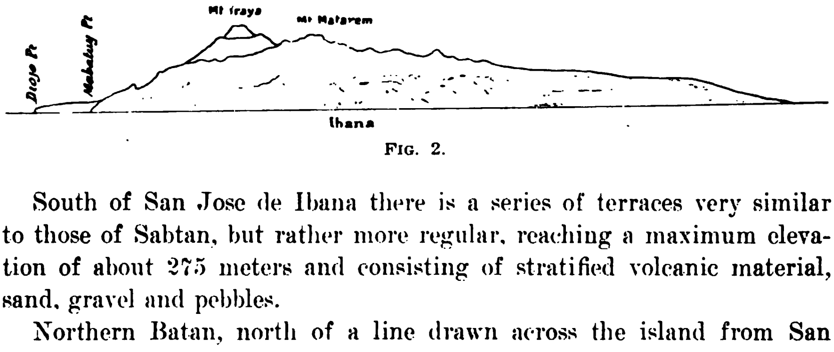

FIG. 2.

South of San Jose de Ibana there is a series of terraces very similar to those of Sabtan, but rather more regular, reaching a maximum elevation of about 275 meters and consisting of stratified volcanic material, sand, gravel and pebbles.

Northern Batan, north of a line drawn across the island from San Carlos de Magatao, shows an entirely different style of topography, the features of the landscape being controlled by the extinct volcano, Mount Iraya. This mountain is a beautifully symmetrical cone, its height as given on the Coast Survey chart being 3,806 feet (1,160 meters). The photograph (Pl. VI) shows that it was once of greater height, an older and larger cone having been blown away in a former eruption and a new one built up in the old explosion crater, while on the southern side there is a hill of tilted basalt which may be the remains of a still older crater. The present crater is horseshoe shaped, being broken down on the northern side where the last lava flow, a stream of basalt, has emerged. Numerous, small fissures are seen in the crater and one cuts across its southern wall. These fissures are probably the result of earthquakes. Nearly all the lava flows are basalt, but the earliest seem to be andesite, although no petrographic study of them has as yet been made.

The end of the flow of basalt from the present crater is exposed in a sea cliff on the northern shore of the island, and this tells in some detail the story of the last eruption of Mount Iraya. The mountain had been quiescent for a period long enough before the eruption to allow a considerable stream valley to be cut through the bedded deposits of volcanic débris which form the cliffs of this neighborhood. The renewal of its activity was marked by considerable explosive force which probably blew away part of the northern side of the present cone and nearly filled the valley with a mass of angular fragments of volcanic material. The latter part of this explosive phase was marked by the presence of a number of basaltic bombs. Finally, a stream of basalt several feet thick flowed down this valley, completely filling it. Since then the lava flow has itself been buried under the mass of loose material constantly creeping down the slopes of the mountain.

The nearly flat region around Santo Domingo and stretching across the island owes its form to the piedmont wash from Mount Iraya. The hyperbolic curve of the mountain must at one time have been continuous from sea level to summit, but marine erosion has cut off the lower end, leaving sea cliffs varying from 15 to 60 meters in height truncating the piedmont plain and of much greater height where the waves have encroached upon the actual slope of the mountain in the extreme northeastern part of the island. (Fig. 3.)

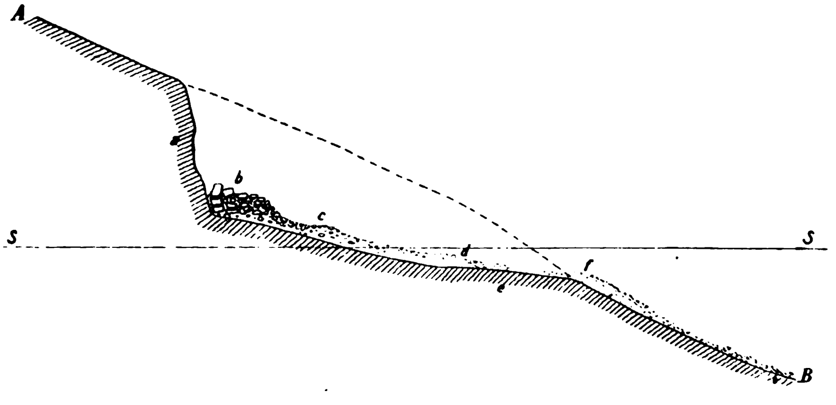

FIG. 3.

The cliffs of the Piedmont region are composed of stratified sandstone and conglomerate, poorly consolidated, and it is only the constant action of the surf that permits such loose material to form cliffs. The pebbles in the conglomerate beds are all of volcanic origin, and cross-bedding is common in the sand and gravel layers, but no distinct ripple markings appear. I found several pieces of wood embedded in various parts of the cliffs, but never any marine shells. All these facts go to show that the conglomerate is distinctly of terrestrial origin. However, northward from Santo Domingo to Diojo Point there is a series of cliffs of coral limestone interbedded with a distinctly marine conglomerate, the latter containing a large proportion of limestone pebbles. The relations between this limestone and the conglomerate just described, which forms the cliffs bounding the Piedmont area, is not entirely clear, but if the coral has grown upon the conglomerate, there may have been some slight reworking of the material by the waves. The extremely flat plain of Vergnung on the east coast opposite Santo Domingo seems to have been planed off by marine action, as rounded pebbles and shells are found on its surface. (See Pl. VI.) It is of course possible that the limestone area north of Santo Domingo may have been an earlier uplift against which the wash deposits from the mountains have been built up.

Santo Domingo de Basco, the capital of the subprovince and the largest town in the islands, owes its prominence entirely to its situation. It possesses the only harbor in the islands with a stretch of beach unobstructed by coral, where boats can be hauled up. It is surrounded by the best farming land and in addition it is the central point for the fertile region around Mount Iraya.

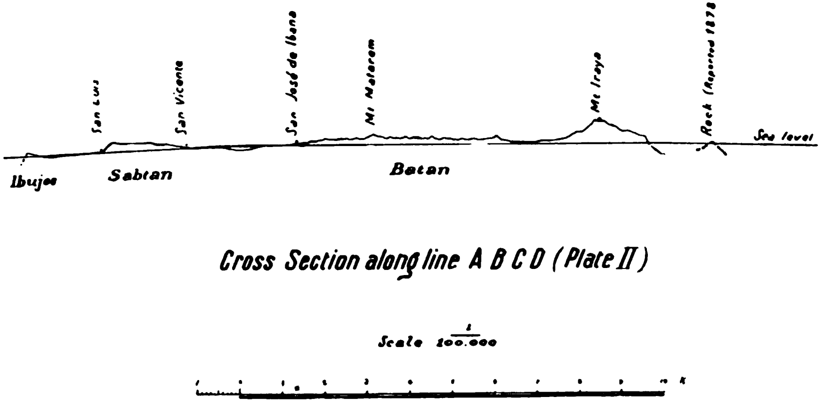

FIG. 4.

Fig. 4 is a cross section through the islands of Ibujos, Sabtan and Batan along the line ABCD of map 2, showing the principal features of the topography.

INEM.

Inem Island, north of Batan, is noted on the chart as "volcanic" and the height is put at over 1,800 feet (550 meters). These two facts represent practically all the information I have been able to obtain concerning this rock. It is a lone rock rising out of the sea, with steep cliffs on every side, and dangerous currents make landing there practically impossible. As seen from the deck of the steamer it is an extinct volcano which has suffered heavily from marine erosion. Reports are current that steam has been observed to rise from its summit, but I am inclined to believe that the small clouds which often hang around the mountain are responsible for this belief.

THE SIAYANES.

The islands lying north of Isbayat are locally grouped together as the *Siayanes*, a word said to mean "good fishing grounds." However, the natives seldom venture north of Isbayat, as there is a strong northerly current which has more than once carried their boats to the Japanese island of Botel Tobago where they have suffered from the attacks of savages.[9] The islands of Siayan and Mabudis of the Siayanes Group, judging from what could be seen from the steamer, seem to be composed of lava flows with a small amount of limestone. Mabudis shows a sharp, irregular peak, possibly an extinct volcano above a fairly level terrace. (See Pl. VIII.) Both of these islands are largely cliff-bound and have probably been separated by marine erosion. North of these is another pair, Y'Ami and May sanga (or North Island). Y'Ami, on which I was able to land for a short time, is a small island of considerable height and, except for a few feet of coral near the shore is composed entirely of volcanic material. There is a considerable quantity of stratified and cross-bedded sandstone in the lower part, above this a volcanic agglomerate, consisting of basalt fragments and bombs. Interbedded with this are several flows of basalt. I did not have time to reach the top of the island and so could not determine whether or not it was a volcano, but from the apparent horizontality of the lava flows I did not consider it probable. The same flows seem to be continued on the neighboring island of May sanga, which is probably separated from Y'Ami by marine erosion. It seems likely that all four of the Siayanes islands, together with their outlying rocks and perhaps Inem and Batan, once formed a single land mass, built up by flows from Mabudis, or perhaps from Inem or even Iraya.

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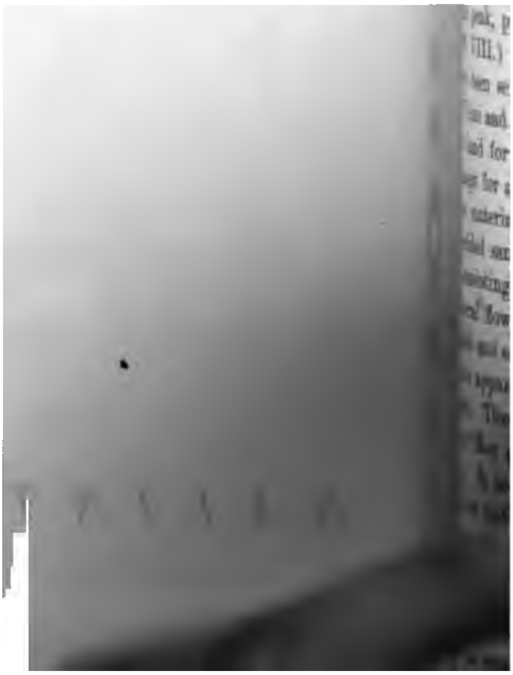
[9] Davidson, J. W.: Formosa, Past and Present (1903) mentions "Bashe" Islanders as being shipwrecked on Formosa and the Batanes people are now living on Botel Tobago.



[illegible]

[illegible] reach the top of [illegible] it was a volcano, but [illegible] I did not consider it [illegible] continued on the neighboring [illegible] The same flows [illegible] which is probably separated from Y'Ami by marine [illegible] It seems likely that all four of the Siayanes islands, together [illegible] perhaps Inem and [illegible] once formed a [illegible] flows from Mab[illegible] [illegible] from Inem [illegible]

[illegible] "Bashe" Is[illegible] are now living

THE LIMESTONE ISLANDS.

The three limestone islands lie to the westward of the rest of the Batanes and topographically are in marked contrast to them.

IBUJOS.

The island of Ibujos consists entirely of coral limestone rising in steep cliffs to a height of over 60 meters. These surround the island, except on the eastern side where the land rises gently from the fringe of sand dunes and small ponds around the shore, in contrast to the 300-meter agglomerate cliffs of the island of Sabtan less than 2 kilometers distant. (See Pl. IX.) The surface of Ibujos is gently rolling, but without any streams or definite stream valleys. This condition is partly due to the solubility of the rock which allows water to run off in underground channels, but it is also in large part an effect of the recent date of the uplift, which has not allowed sufficient time for the streams to form valleys. The soil seems to be volcanic ash rather than limestone.

DESQUEY.

Desquey, a little island to the west of Ibujos, is entirely cliff-bound and inaccessible, but otherwise seems to be exactly like Ibujos.

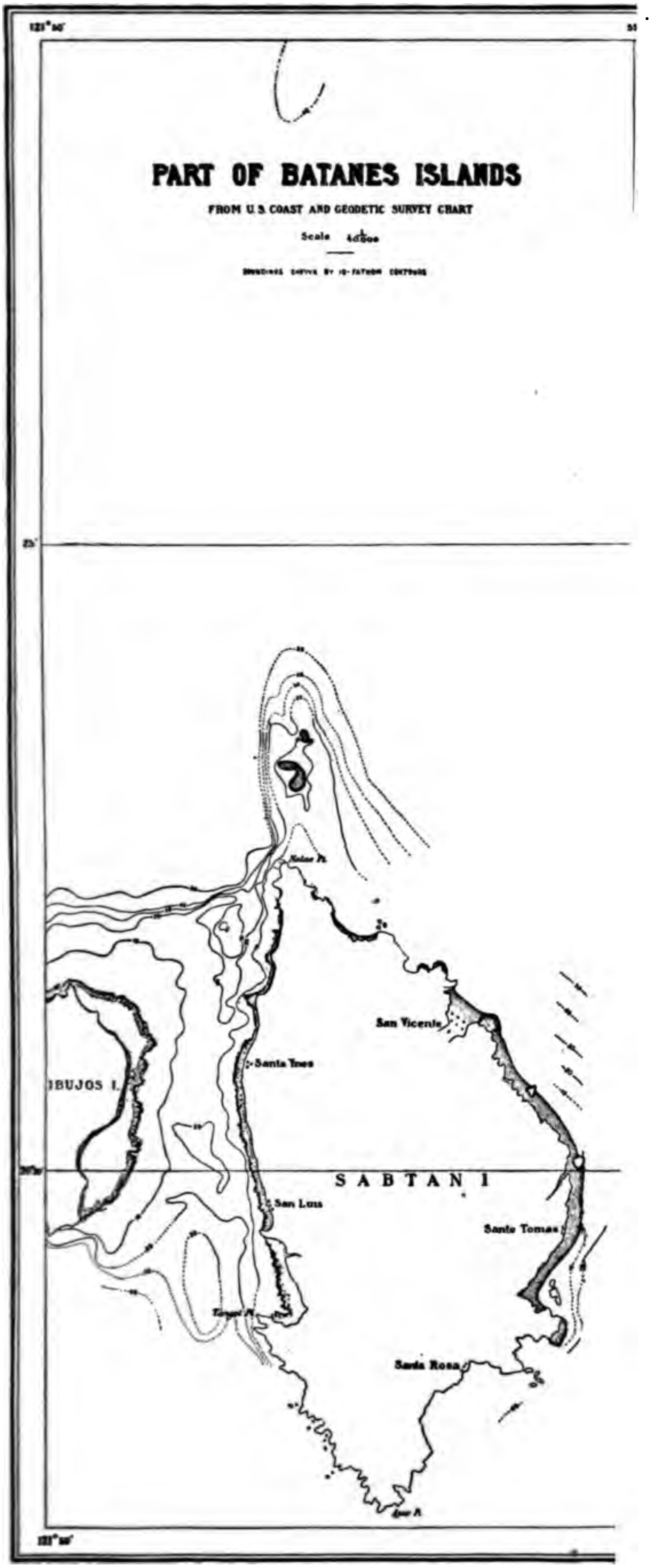
ISBAYAT.

Isbayat, the largest island of the group is likewise entirely surrounded by cliffs, the only landings being steps cut in the rock in one place, and a series of ladders in the other. From the deck of the steamer the cliffs seemed to be similar to the limestone cliff of Diojo Point on the north of Batan Island, and I am told by people who have visited the island that the land slopes downward from the top of the cliffs toward the villages which are situated in small "sinks." This fact inclines me to believe that Isbayat is formed of limestone, rather than that it is of volcanic origin. The island is said to be the most fertile of the group, but has a reputation for unhealthfulness, the natives of the other islands suffering from fever whenever they go there. Between Isbayat and Batan, and in a less degree throughout all the islands, there are extremely powerful and complex tidal currents which render the passage between the individuals of the group extremely dangerous, so that almost the only communication with the outside world is when an occasional steamer takes on a load of cattle from the Isbayat pastures.

SUBMARINE CONFIGURATION.

The soundings given on the chart are very few and these for the most part (see map No. 3) do not reach to bottom, but record "no bottom" at depths of from 25 to over 100 fathoms. However, meager as the information is, it will be of interest to examine it in some detail.

South of Botel Tobago there seems to be a bench of about 100 fathoms


121° 50'
PART OF BATANES ISLANDS
FROM U.S. COAST AND GEODETIC SURVEY CHART
Scale 1/40000
SOUNDINGS SHOWN BY 10-FATHOM CONTOURS
25'
San Vicente
Santa Ines
IBUJOS I.
20° 20'
SABTAN I
San Luis
Santo Tomas
Santa Rosa
121° 50'

Map No.

in depth extending as far as Gadd Rock, about 31 kilometers south of the island of Little Botel Tobago, where it ends sharply in the deep Bashi Channel. Between Botel Tobago and Formosa, on the other hand, a depth of 1,050 fathoms (without bottom) is reached. From Formosa a similar ridge extends southwards for about 90 kilometers where a sounding of 73 fathoms is recorded, but beyond this there seems to be a marked deepening to the southward. The "position doubtful" Mark Lane Shoal in latitude 21° north, longitude 120° east may be a part of this same shelf. A line of deep soundings through the Bashi Channel gives the following depths: 2,645 fathoms, 55 kilometers east-northeast of Botel Tobago; 2,618 fathoms, 40 kilometers east of Little Botel Tobago; 1,287 fathoms, 27 kilometers east-southeast of Gadd Rock; 1,009 fathoms, midway between Gadd Rock and Y'Ami; 2,009 fathoms, 40 kilometers west of Y'Ami; 2,053 fathoms, the same distance west of Isbayat; 1,784 fathoms, 55 kilometers west-southwest of Isbayat, and 936 fathoms, 73 kilometers west-southwest of Desquey. These soundings seem to show the existence of a deep trough connecting the "deep" off the west coast of northern Luzon with that to the southeast of the Riukiu Islands.

On the American side of the Bashi Channel the soundings are those made by the British survey of 1845 and are for the most part "without bottom" and hence of less value for our purposes. No soundings are given in the vicinity of Isbayat and the Siayanes, except between Y'Ami and May sanga where there is a minimum depth of 36 fathoms, probably from tidal scour and recent depression.

Between Ibujos and Sabtan there are for some reason a great number of soundings, generally less than 20 fathoms. The most interesting feature of these is a narrow trough of from 19 to 45 fathoms depth close to the northern part of the west coast of Sabtan. Another feature is the sudden deepening beyond 20 fathoms, the 20- and 30-fathom countours being in most cases close together. There are very few soundings to bottom near Batan Island, but such as are given seem to indicate the existence of a 20-fathom shelf.

GEOLOGIC PROBLEMS.

Having given a general description of the islands it seems advisable briefly to touch on the chief geologic problems before proceeding to a physiographic discussion.

THE ORIGIN OF THE AGGLOMERATE.

The volcanic agglomerate, so far as we can see, is the basal rock of these northern islands. In thin sections of limestones which rest upon it, Mr. W. D. Smith has found the Miocene fossils *Orbitoides* and *Lithothamnium*, hence the agglomerate may be considered pre-Miocene. Thus, in accounting for its origin, hypotheses depending on existing physiographic forms, such as the explosive activity of Mount Iraya or an explosion crater in the amphitheatral valley north of Itbod, are untenable. Mr. Smith [10] has discovered volcanic agglomerate of probably similar age in Ilocos Norte, hence a proper explanation should include both. The Babuyanes Islands have a roughly circular form and might be considered as a large explosion crater but for the fact that they, like the Batanes, are divided into an eastern volcanic group and a western group of coral islands, and as in addition no such agglomerate is found on Camiguin, the only island of the group which the writer has been able to visit. From present knowledge the most that can be said in regard to the origin of the agglomerate is that in pre-Miocene times enormous, explosive, volcanic activity between latitudes 18° 30′ and 21° north built up a land mass in the region of the Batanes Islands and a considerable mass of agglomerate in Ilocos Norte near Cape Bojeador. The northern part of Luzon eastward from the *Cordillera Central*, is as yet unexplored and hence it is impossible to say how great an area this agglomerate may cover.

FAULTING.

The difference in structure and topography between the neighboring islands of Sabtan and Ibujos is extremely striking, the former having on its western side a straight line of agglomerate cliffs, reaching an altitude of about 400 meters and broken only by narrow cañons, with the fall-line close to the sea, and the latter being composed entirely of limestone (age as yet undetermined) rising gradually on its eastern side toward the west. This striking difference of material and topography, together with the straight coast line of the western side of Sabtan and the trough just off the Sabtan shore, to say the least, strongly suggests a fault line between the two islands, with upthrow on the east. If we accept this fault on the evidence as given above and prolong it to the north and south we obtain some suggestive results. Extending the line northward in a direction N. 6° 35′ E., brings Isbayat (probably similar to Ibujos) to the west of the line and the Siayanes and Inem (neo-volcanic) on the eastern side. Following the same line to the southward there is a similar division of the Babuyanes Islands, the Balingtang rocks (probably volcanic), Babuyan Claro, Camiguin and the Didicas rocks all lying to the east of the line, and Calayan, Dalupiri and Fuga (Babuyan) to the west. This line further extended would meet Luzon at the mouth of the Cagayan River.

ALIGNMENT OF VOLCANOES.

The close alignment of both active and extinct volcanoes along the one hundred and twenty-second meridian is remarkable. The following are the longitudes: Y'Ami Island, 121° 58′; Mabudis Island, 121° 57′; Inem Island, 121° 57′; Mount Iraya, 122° 01′; Balintang Rocks, 122°

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[10] Smith W. D.: *This Journal, Sec. A, Gen. Sci.* (1907), 2, 153.

08′; Babuyan Claro, 121° 56′; Camiguin Volcano, 121° 52′; Didicas Volcano, 122° 09′, and Cagua Volcano, in northeastern Luzon, 122° 04′. It seems reasonable to infer from the close alignment of the volcanoes of the Babuyanes and Batanes groups and the supposed fault between Sabtan and Ibujos, that the volcanoes mark a fissure in the earth's crust and that their activity may be dependent upon sea water having had access to great depths along the fault.

CORRELATION.

There is not enough material at hand just now to enable us to determine the tectonic relations of the Batanes with Formosa and with the Babuyanes and northern Luzon. However, there are certain significant facts. First, the enormously deep Bashi Channel seems to trend in a northeasterly direction. If so, it may represent a geosyncline or trough, parallel to the tectonic lines shown by Von Richthofen along the southeast coasts of China and Cochin-China and to the northwest coasts of Borneo and Palawan. This deep channel prologed, would enter the 4,000+meter "deep" of the northwest coast of Luzon and follow the 2,000+meter "deep" to the southeast of the Riukiu Islands, hence, by inference, making the Philippines and Japan (including Formosa) separate geologic provinces. Professor Kôtô[11] sums up the present geological knowledge of Botel Tobago (Kôtô) as follows:

> "Fringing reefs are said to skirt the shore, some portion attaining double man's height above the water's edge, indicative of a recent negative shift of the relative levels. It seems to me probable that they are not the reefs of Neocene time, which usually attain a considerable height of more than 200 meters as in the Apes Hill of Takao, but those of a comparatively recent date, possibly representing a *diluvial formation*. The plateau-like elevation, which faces the sea in cliffs, seems in parts at least in the northeast point to consist of volcanic agglomerate. A greater part of the interior seems to be built of volcanic rocks with a gabbro-like plutonic mass as the foundation of the island exposed at the west coast, but their mutual relations and area of distribution are quite unknown to me."

Professor Kôtô also gives petrographic descriptions of feldspar basalts, hornblende andesites, apoandesites, gabbro and serpentine from Botel Tobago.

Thus, the existence of a volcanic island in longitude 121° 30′, although across the Bashi Channel from the Batanes and the great Taito furrow running N. 20° E. from the southern point of the island,[12] together with the Taito Range just to the east of it, may be more than mere coincidences.

The chain of volcanoes is certainly significant in regard to the relation of the Batanes Islands to the Babuyanes and northern Luzon, as is also the separation of the limestone islands of the groups from the volcanic ones.

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[11] *J. of the Coll. of Sci. Tokyo* (1900), **13**, 46.

[12] Hobbs, W. H.: *Am. Geol.* (1904), **24**, 374.

Furthermore, the earthquake records seem to show a closer connection between the Batanes Islands and the northeast of Luzon than with the northwest.[13] However, these points of tectonic geology will be discussed more fully in a subsequent paper.

PHYSIOGRAPHY.

FORMATION OF THE LAND.

The first geologic action of which we have any definite record is the building up of the agglomerate, by explosions from somewhere to the southward. At a moderate estimate the agglomerate formation has a volume above sea level of between 1½ and 2 cubic miles, and the amount of erosion undergone by the islands shows that this figure represents a small fraction of the original volumes. That the agglomerate was not built up in a single explosion is shown by the areas of stratified sandstone and conglomerate which occur here and there throughout the formation, showing that there were periods of quiescence of sufficient length to allow streams to work during this period. Nothing can be said concerning the region in which the explosions took place except that it was of volcanic formation, for only lava pebbles are found in the agglomerate and this lava is practically all andesitic.

THE SABTAN UPLAND.

The first record of the physiographic cycle is found in the upland of Sabtan. This belt from 300 to 400 meters above the sea shows a topography which if not that of a peneplain, is at least in advanced "old age" and represents the cycle previous to the present. It is of pre-Miocene age, since Miocene limestones are found on the eastern flanks of the plateau. We have then at the commencement of the latest physiographic cycle in pre-Miocene time, a low-lying land mass without marked relief covering at least the area at present occupied by the islands of Desquey, Ibujos, Isbayat, Sabtan, and Batan.

PERIOD OF UPLIFT AND EROSION.

The next chapter in the history was one of uplift, accompanied by pauses in which the limestone terraces of Batan and Sabtan were formed, and possibly by some oscillation. However, this uplift was too rapid for the streams to keep up with it and the present topography of the agglomerate area is characteristically "young," most of the streams flowing through typical box cañons.

A peculiar feature in the drainage conditions of Batan is the amphitheatral valley north of Itbod. This is a wide, open valley of irregular, ellipsoidal shape, inclosed between ridges of agglomerate and cut up by spurs running out from these ridges. The streams here have gentle gradients and gently sloping banks. In the central part of this valley outcrops of andesite are found, one of which shows a wide zone of pyritized attrition clay, with a northwesterly strike, the result of faulting.

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[13] Maso, Rev. M. Saderra, S. J.: Philippine Census (1905), 1, 246.

The two streams draining this valley flow to the southward, cutting through the Matarem range which here runs east to west, in steep cañons, uniting at the barrio of Itbod. The eastern of these two streams can be followed from Itbod to within a short distance of the point where the broad valley begins. It flows through a very narrow gorge generally less than fifteen meters in width, with walls over sixty meters in height. Waterfalls are frequent.

There is no reason why the valley should not be readily explainable by superimposed drainage. The presence of a fault the strike of which is parallel to the long axis of the valley is probably sufficient to account for this. A shattered fault zone would readily yield to erosion and be worn down to the grade determined by the rate of cutting of the stream through the well cemented material to the south. Hence, the part of the stream and its tributaries in the region of the fault zone would be practically at grade, only cutting down the valleys as the deepening of the cañon gave them new power. Thus, there is a gradual "sinking down" and preservation of mature topography from a previous cycle in a present extremely youthful stage. It seems strange that the stream draining the valley should not flow along the line of the faulting to the southeast, where the hills are lower, instead of directly through the highest part of the ridge. As it does not, there is evidence that the drainage conditions which existed before the uplift began, are now superimposed upon the younger topography. Eventually, if conditions remain unchanged a stream working up along the fault zone from the southeast will capture the headwaters of the present streams. It may already have done so in part, but without a topographic map the dense vegetation makes it impossible to secure any grasp of the details of the physiography. The two streams which at present drain the valley are also engaged in a struggle for supremacy. The eastern of these, having the shorter course, can make steeper grades and hence will eventually have the advantage, but at present this seems partly neutralized by the otherwise more favorable situation of the western one, which receives the drainage from the Matarem Range. However, it seems probable that the eastern stream has already captured an eastern branch from its neighbor.

A peculiar feature of drainage conditions in general is the small amount of work accomplished by the streams in a region of such heavy rainfall. The older topography of Sabtan is of pre-Miocene age and is at an elevation of over 300 meters, hence it seems strange that any of it, far less such a large belt, should still exist. One reason for this condition is undoubtedly the smaller drainage basins of these islands as compared with mainland conditions. The erosive power of streams is dependent very largely upon the size of their drainage area. The one of two streams receiving more water because it has a larger drainage area, has the advantage over one with a slightly better grade, but a smaller drainage area. Hence, we must not look for the same proportion of work of stream erosion on small islands as would be found on Luzon. However, another point to be considered here, is that the present strip of Sabtan upland is bounded on the west by a fault scarp and that the western streams have scarcely begun their work.

SINKING OF IBUJOS-DESQUEY.

The sinking of the land to the west of Sabtan must have taken place toward the end of the uplift, for the western coast of Sabtan shows no traces of terraces or other evidence of having been submerged. Probably the period of greatest movement was contemporaneous with that of greatest activity among the volcanoes to the east of the line of faulting. Movement along this line is in all likelihold still progressing. This is indicated by the prevalence of earthquakes in the Batanes, where the records for 1906 show eleven shocks, as against three at the mouth of the Cagayan River (Aparri) and on the northwest coast of Luzon (Vigan).[14] In five years (presumably 1898–1902) only twenty-five earthquakes were recorded in the southern part of Formosa (Taiku).[15]

The downthrow of the western part of the older plateau could not have depressed the land to a point below that at which coral can grow (100 fathoms). Coral, formed upon this depressed shelf and later elevation affecting both sides of the fault, with perhaps some reverse movement of the fault blocks, has brought the western islands, Ibujos, Desquey and Isbayat to their present elevation.

DEPRESSION.

It is not to be supposed that the period of uplift was uninterrupted. The benches which give us our evidence of elevation are in themselves indications of stationary periods and hence it is not improbable that, although uplift has been the dominant feature of the history of the islands, there also may have been small periods of depression or tilting. The persistence of the 20-fathon shelf around Sabtan and Batan and the submarine contours of Santo Domingo Bay (Map No. 3) may indicate a depression. On the other hand, this 20-fathom shelf may be indicative of the amount of marine erosion accomplished during the time that the islands have remained at their present level, showing the depth to which wave action is effective in the region. The islands, as has already been stated, lie in the track of the majority of the typhoons, hence marine erosion must be a very significant feature. It is to be regretted that there are no soundings on the Pacific side of Batan, as it would tend to clear up this point if we knew whether this submarine shelf were deepest on that side. Naturally, where open to the Pacific, the waves would have greater force than on the western side, hence it is to be expected that if the typhoon waves of the China Sea are effective to a depth of 20 fathoms, those of the Pacific should cut a deeper bench.

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[14] Algue, J.: Monthly Bulletins of the Observatory, Manila, 1906.

[15] Davidson, J. W.: Formosa, Past and Present (1903.)

MARINE EROSION.

In all probability Ibujos and Desquey were one island within recent geological time, as was the case with Siayan and Mabudis and also Y'Ami and May sanga. It is not improbable that Isbayat may have been separated from the other limestone islands by marine erosion, and that the four Siayanes Islands may at one time have formed one island. If this is so, then the amount of land lost through marine erosion must nearly equal the present area of the islands.

The land, at least Batan Island at the present time, is essentially stationary. This is shown by the high sea cliffs of unconsolidated material around Mount Iraya. A sea cliff represents the shoreward limit of effective action of storm waves. The action of waves upon the coast, in addition to the formation of a cliff, tends to build out a submarine shelf, partly through cutting away the land and to a less degree by depositing the material carried out by the undertow. The relation of this shelf to a receding cliff must always be such that the shelf must be kept worn down to such a depth by the abrasive action of material carried out by the undertow, that the waves will be able to do effective work against the cliffs. The analogy to stream conditions is very close. Under normal, stationary conditions of the land the undertow near the coast acts in time of storm as a degrading stream, the force of the waves hurling pebbles against the face of the cliff, loosens great blocks which are later broken up to a size suitable for transportation. These are carried seawards by the undertow which has sufficient force to keep the wearing down of the beach and shelf in such relation to the point where the waves are tripped, that the latter are able to do their most effective work on the cliff and to keep the undertow constantly supplied with new material. When the undertow reaches deeper water it necessarily has less velocity and consequently less carrying power. The material borne out is therefore deposited, the coarser nearer shore and the finer farther out, just as a stream degrading near its head deposits its material when its velocity and carrying power become less. Since the carrying power of the undertow varies as the 3/2 power of its volume and the sixth power of its velocity,[16] it is clear that only during times of storms is it as effective as a degrading stream. Marine erosion may be tremendously effective during the progress of a tropical cyclone. This is shown by the fact that in the vortex of the typhoon the elevation of the water level, due solely to decrease in pressure of the atmosphere, may amount to nearly a meter.[17] A long period without storms has the same effect on coastal erosion as a similar one without floods has upon stream erosion. The waves, having less force, are no longer as effective upon the cliffs and the weaker undertow is compelled to deposit its material nearer shore, building up an additional bench of loose detritus which is carried away by the next storm, just as the deposits made by a stream of small transporting power are carried away in times of flood. When elevation of the land occurs, no matter how small, the delicate relation between bench and cliff is destroyed, waves are tripped before they can do effective work upon the cliff and the result is first, a protecting reef which must be planed down before the cliff can again be attacked, and, if elevation continues, a raised bench. If, on the other hand the land is depressed, the waves beat directly upon the cliff. In the deeper water the undertow is less effective as a transporting agent and must deposit the material fed to it by the waves until it has built up its bench to "grade."

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[16] Gilbert, G. K.: *U. S. G. S. 5th An. Rep.* (1884), 89.

The material deposited by the undertow at the end of the bench comes into the power of the shore current. The action of this current is extremely variable, depending upon the prevalence of onshore winds and the shape of the coast line. Its action is always to simplify the coast line by depositing its load in and across the deeper reëntrants. On the coast of Batan this current should be strong during the prevalence of steady monsoon winds, although it is complicated by and subordinate to the tidal currents. Fig. 3 (p. 9) modified from Gilbert,[18] illustrates the formation of a sea cliff, on a coast having an original outline of AB. Beginning with the sea cliff (*a*) in this diagram, we have first, an upper bench (*b*) composed of large blocks broken off from the cliff and of slightly rounded bowlders. This is only reached by the waves of the heaviest storms. Below this bench there is another ledge (*c*) the material of which is worked over by waves of ordinary storms and is consequently composed of smaller bowlders. Beyond this is the beach (*d*) of material progressively smaller towards the sea. This beach is being gradually built up in ordinary weather, but in time of storm it is moved by the undertow which erodes the ledge (*e*), to a point where the waves when breaking do their most effective work on the cliff. Farther seaward at (*f*) is the extension of the terrace built by the storm undertow:

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[17] Algue, Rev. J., S. J.: The Cyclones of the Far East. Weather Bureau, Manila (1904), 173.

[18] *Loc. cit.*, 84.

the extent of this at any given point depends upon the strength of the shore current at that point. The features (*c*) and (*d*) belong to periods of moderate weather and hence are constantly being destroyed and rebuilt.

It is clear in the case of the cliffs of poorly consolidated conglomerate surrounding the northern part of Batan, that they could not retain their present form without constant cutting by the waves. Hence, the land can not be rising, for otherwise the elevation of the bench would cause the waves to trip before reaching the cliff, and the cliff, left to the disintegrating action of the atmosphere and ground waters, would slump down until the angle of rest of its material is reached. On the west coast of Isbayat there is a considerable depth of water very near the shore and there is no beach between the cliffs and the sea. This indicates recent depression.

TIDAL SCOUR.

The tidal scour is another marine agency which must have considerable effect. The tidal wave between the Pacific and the China Sea must pass through the Bashi and Balingtang channels. Consequently, the wave is narrowed, its force increased and an extremely complex series of strong tidal currents is created throughout the islands. It is to be expected that these currents should have some effect upon the submarine configuration and it seems likely that the channel of Santo Domingo Bay and that between Sabtan and Ibujos while possibly of terrestrial origin, owe their present depth and preservation to tidal scour. The depth at present of the channel between Y'Ami and May sanga is undoubtedly due to the tide.

CORAL.

The upbuilding accomplished by the coral is opposite to the destructive agencies of waves and tide. There are few coral reefs in the more exposed portions of the islands, such as the northern and eastern coast of Batan, but growing coral is found everywhere in the more sheltered portions. Beginning on the north side of Santo Domingo Bay there is a series of small coral reefs extending along the west and south shores of Batan as far as Disiai Point. There is only a small amount of coral growing in Santo Domingo Bay, probably because of the sediment brought down by the stream from Mount Iraya; the reef is also broken by small channels, due to streams, which determine the position of the barrios of San Carlos de Magatao, San Vicente, San Jose de Ibana, San Antonino and Itbod. Besides this the points of Chaua, Mabatuy and Mabien stand out beyond the reef. The reef on Sabtan is more extensive, forming a barrier around the island which is broken only by small channels at San Vicente, Santa Rosa and Santa Inés, and at Natao and Ajao Points. There is no inlet at the barrio of San Luis, making it necessary to launch the boats across the reef at high tide, often a dangerous proceeding. However, the barrier reef reaches its greatest development on the eastern shore of Ibujos; there it has a width of nearly a kilometer, and is unbroken by any inlets. On the west shore there is no coral and the limestone cliffs sink sharply into deep water. The same is true of the cliff-bound island of Desquey.

VULCANISM.

Volcanic activity may be regarded as a physiographic accident, interfering with, but independent of the normal cycle of uplift, erosion and ultimate peneplanation. In the history of the Batanes, vulcanism has played an important part. The islands themselves owe their origin to volcanic outbursts of some kind and volcanic activity has been a factor in all stages of their history. There seem to have been periods of lava eruption during the time that explosive outbursts were building up the agglomerate mass. This is shown by the andesite of Natao Point, which may be a flow. The lavas which have extended from the Batanes volcanoes are all basic, consisting of andesites and basalts, and although no general series can be made out, the more recent of them seem to be the more basic.

Volcanic activity during the period of pre-Miocene degradation, is shown by the dikes which cut through the agglomerate, particularly near Ajao Point in Sabtan. During the time of uplift, the *locus* of volcanic action seems to have shifted to the east and north, building up the Siayanes, Inem and Iraya. Activity gradually died out, first at the north, and now the only volcano of a chain of three and possibly four which retains its symmetrical form is Mount Iraya, with its double (or triple) crater indicating long periods of quiescence between those of activity. The present interval of quiescence has lasted so long that the volcano has passed through the solfataric and hot-spring stage, the center of activity having shifted still farther to the southward, to the Babuyanes Islands. The history of the Batanes Islands may be looked upon as a constant struggle of the land for its existence, with vulcanism and coral reef-building in opposition to marine, and to a less degree, stream erosion, uplift and depression being the factors really controlling the struggle.

HUMAN RESPONSE TO PHYSIOGRAPHIC CONDITIONS.

The natives of Batan and Sabtan were divided into three warring clans whose boundaries depended upon topographic features before the coming of the Spaniards and the abandonment of their savage life. In Sabtan, where communication is easy on the east coast, the people were united under one chief. Batan, on the other hand, having a natural barrier in the range running west from Mabatuy point was divided into two clans. The earlier village-forts were naturally built upon commanding eminences, but with the abandonment of tribal warfare defense was no longer a consideration and the sites were selected first, where gaps in the reefs allowed water communication and second, with respect to the amount of arable land in the vicinity.

The region around Santo Domingo owes its superior agricultural advantages to the piedmont deposit of gravel and fine volcanic material from Mount Iraya. Rocks weather to form the same kind of soil in the agglomerate regions of the island, but there the topography, marked by a series of ridges and cañons, makes conditions unfavorable.

In this connection it may be well to note a point of danger to much of the arable land of the Batanes. A large proportion of the cultivated fields is upon steep hillsides, and the trees have been entirely cut away from the ridges. The result is a gradual creeping down of the soil toward the sea. In some places this has gone so far that large cracks have been formed, which follow the ridges for considerable distances. Unless some reforesting is done along the tops of these ridges to hold the soil, much valuable land will be lost. On the sides of the valley just north of Santo Domingo, hedges around the fields seem to have held the soil sufficiently to prevent cracks from forming.

The natives of Batan and Sabtan owing to their isolation have become a race of excellent seamen and boat builders, in comparison with the slovenly seamenship and low constructive ability of the Ilocanos of northern Luzon. Their small boats, or *tatayas,* built somewhat after the fashion of a dory, are excellent surfboats and quick to answer the helm. They make frequent trips to Aparri in their large boats, built somewhat like a Chinese junk, and sometimes they even sail as far as Manila to sell their hogs and cattle. These larger boats are built and owned by the communities. A knowledge of the intricate tidal currents plays so great a part in the life of the people that the best pilots are the most important men of the community.

The natives of Isbayat, being more completely isolated through poorer facilities for communication, have retained more independent characteristics, such as their own language and their peculiar art of basket making. This island owing to its reputation for unhealthfulness, receives no immigrants and is consequently underpopulated and largely given over to pasture land.

SUMMARY.

In pre-Miocene times a land mass of considerable extent was built up by enormous explosive eruptions from unknown sources and, after the cessation of these explosions, was gradually worn down by streams to an extremely mature topography.

The next stage, from the Miocene to recent times, was one of predominant uplift, limestone containing Miocene fossils being found at elevations up to 275 meters. This period was marked by renewed activity of the streams and the cutting of steep cañons. The *locus* of volcanic activity is now shifted from the region of Sabtan to a line along the one hundred and twenty-second meridian.

Faulting between Ibujos and Sabtan cut off part of the old upland, leaving a well-marked fault scarp along the west coast of Sabtan and growth of coral and later elevation brought a limestone mass, of which the islands of Isbayat, Ibujos and Desquey are remnants, to the surface. It seems probable that this fault extends southward through the Babuyanes group and it is possible that the Cagayan valley may represent its continuation in Luzon. The large number of earthquakes recorded in the Batanes indicate that movement along this fault is still going on.

The recent history of the Batanes Islands is mainly one of lessening of the area. The land appears to be stationary and nothing is gained through uplift. The upbuilding force of vulcanism has ceased, leaving the growth of coral reefs the only force acting in opposition to the erosive action of the waves, streams and tides. The work of man in deforesting the ridges is assisting in the wearing down of the land.

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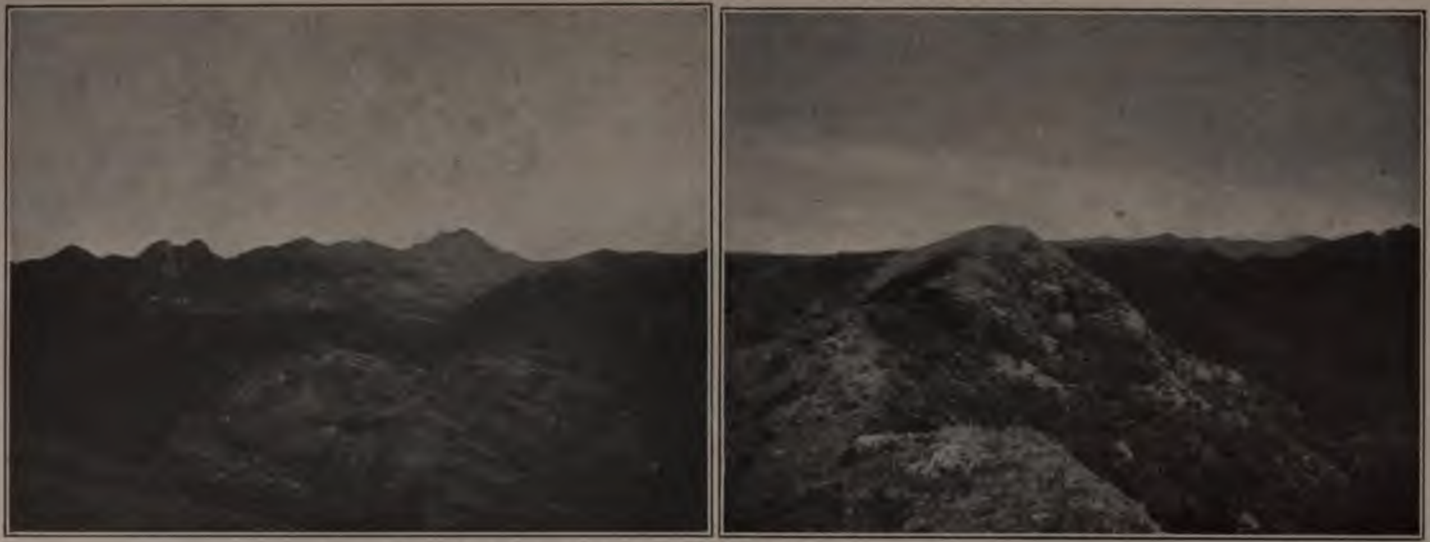

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(Photo by Worcester.)

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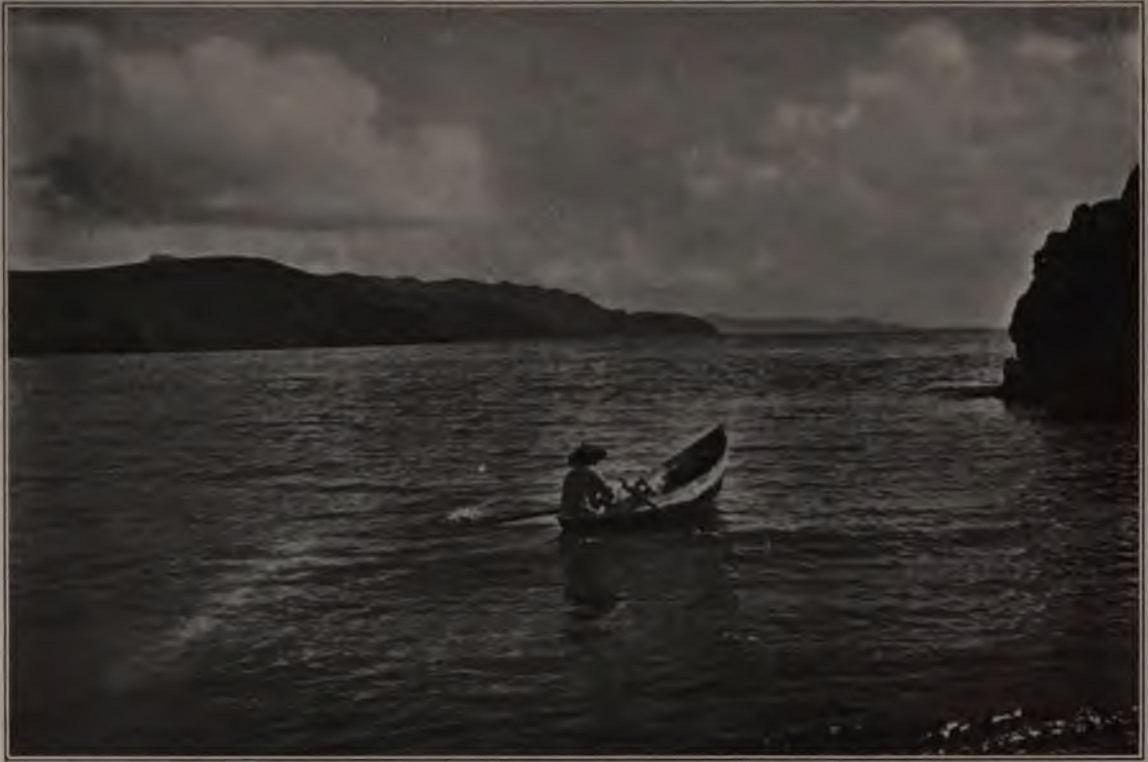

(Photo by Worcester.)

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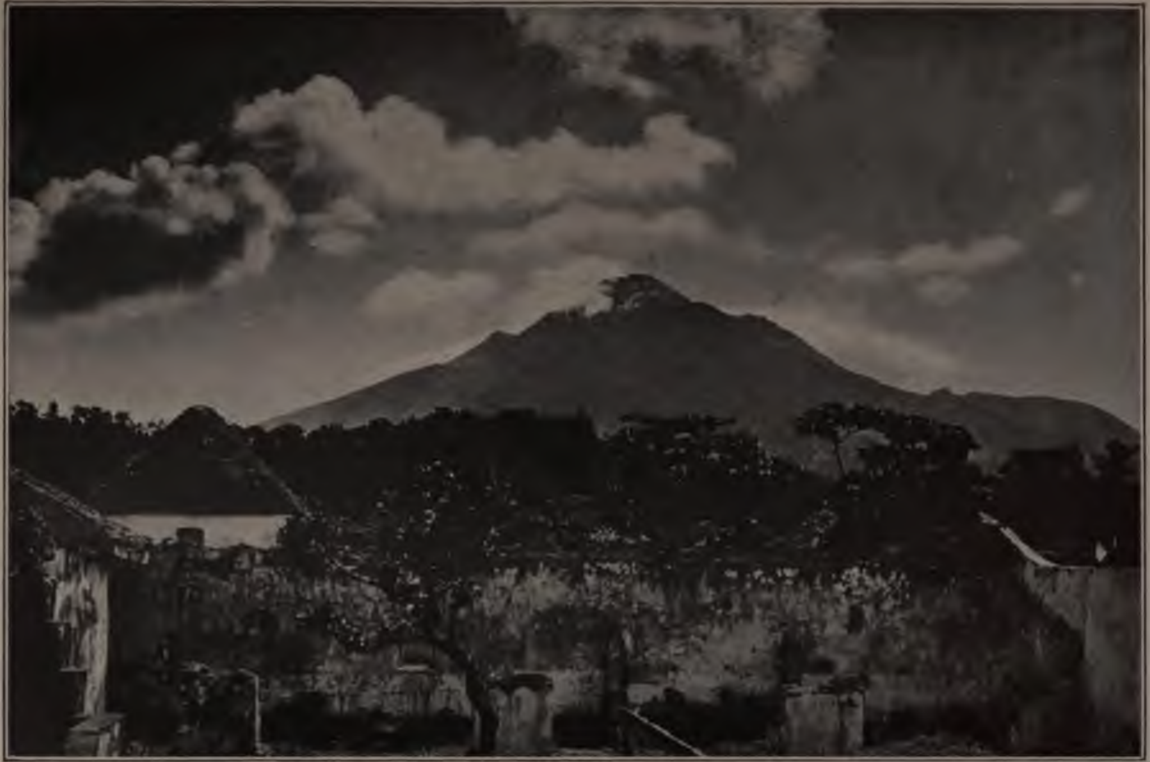
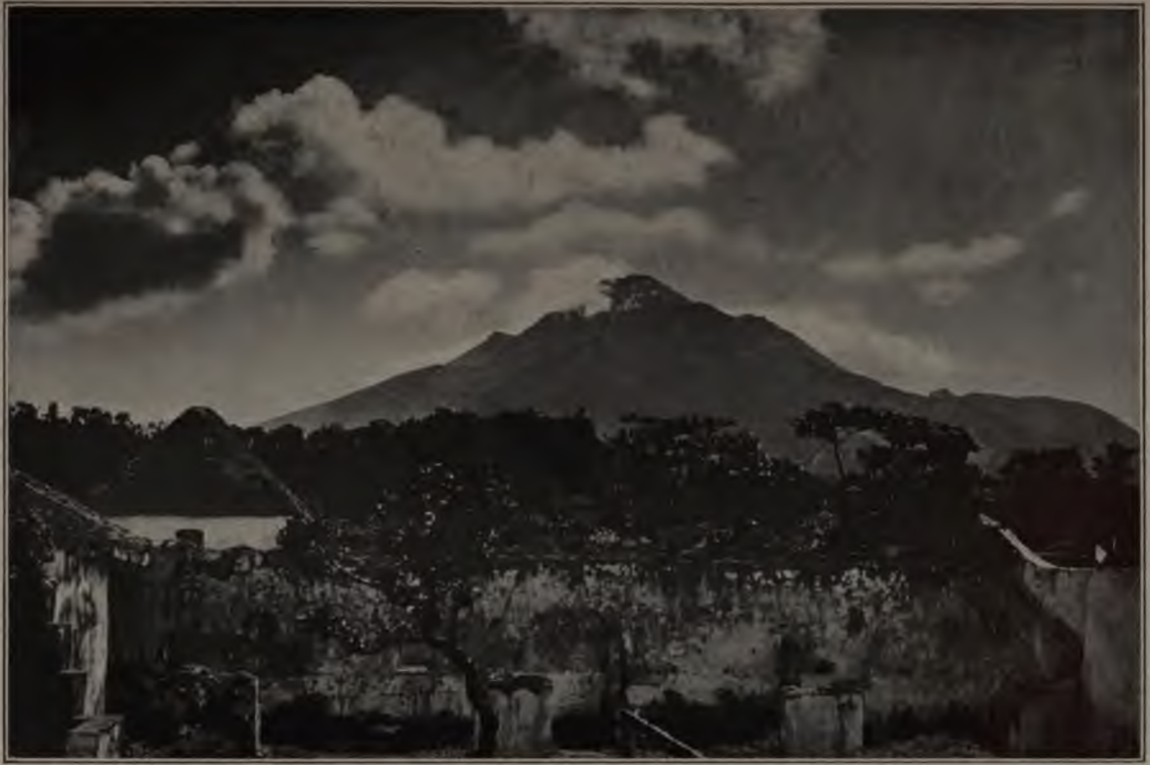


(Photo by Worcester.)

PLATE V. MOUNT IRAYA FROM SANTO DOMINGO.

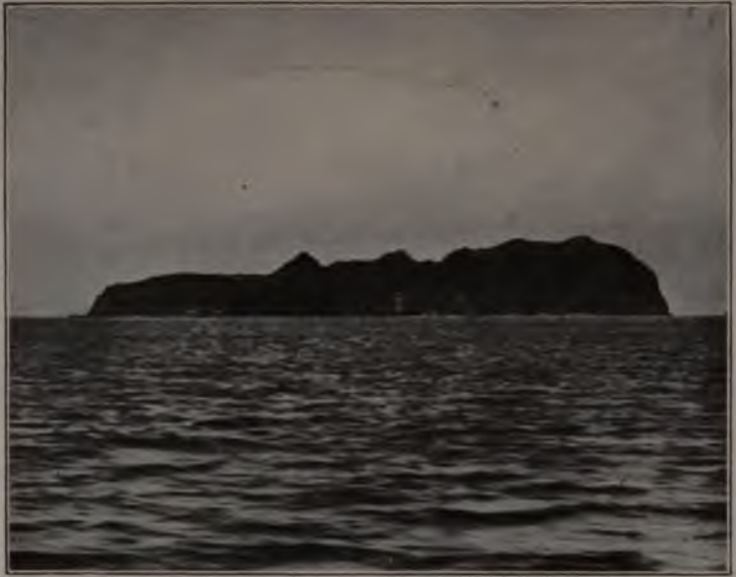


(Photo by Worcester.)

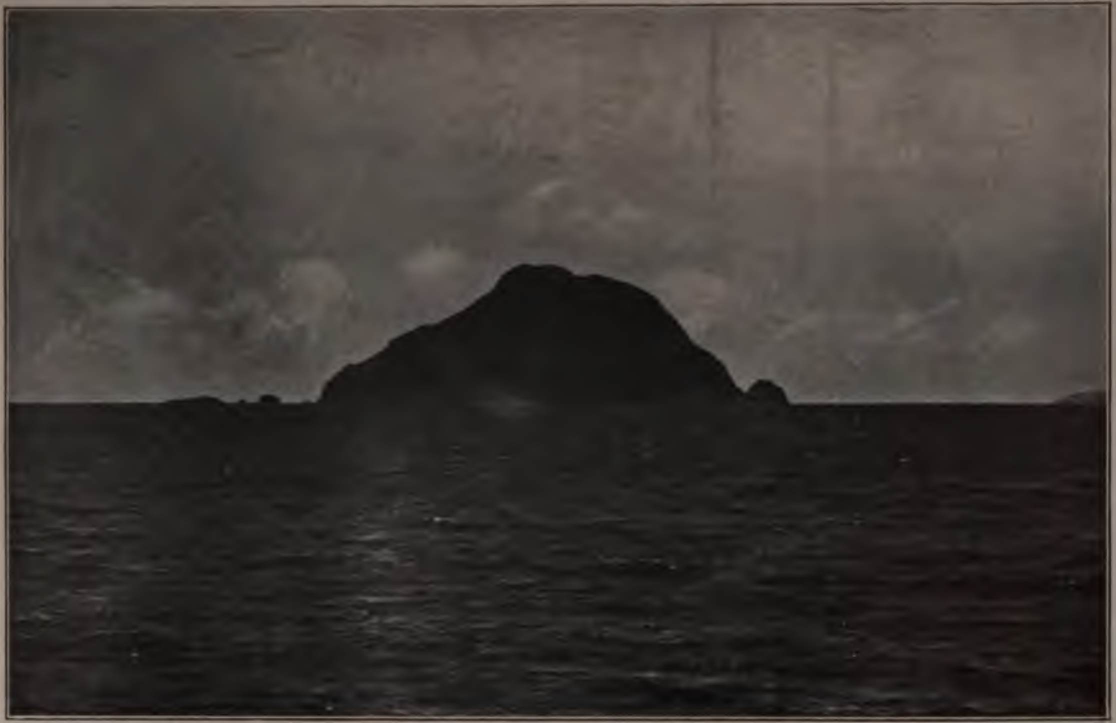
PLATE V. MOUNT IRAYA FROM SANTO DOMINGO.

FERGUSON :

(Photo b



(Photo by Worcester.) PLATE VII. INEM ISLAND.



(Photo by Worcester.)

PLATE VIII. MABUDIS ISLAND, FROM THE EAST.

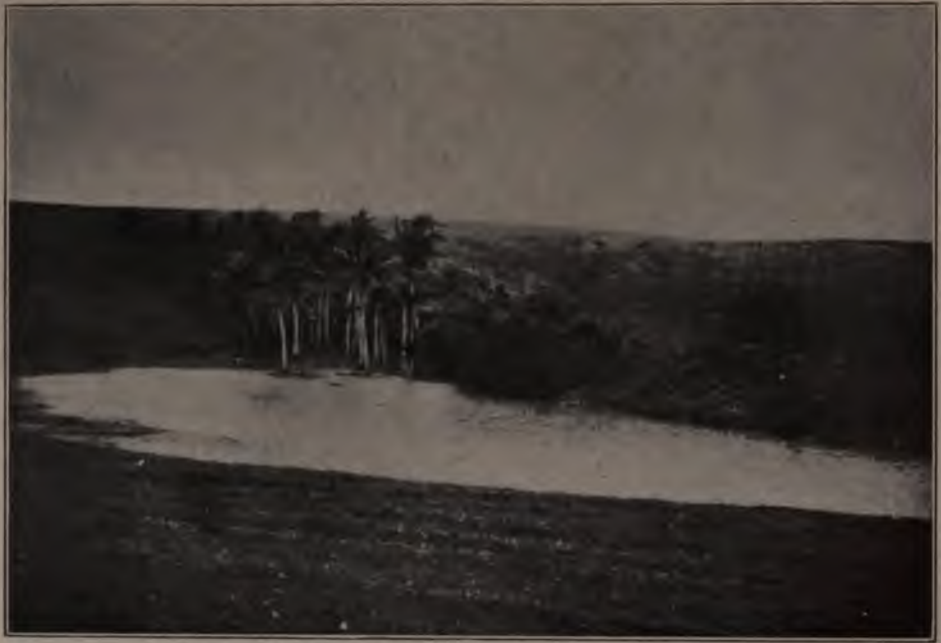


PLATE IX. TOPOGRAPHY OF IBUJOS ISLANDS.

NEW AND LITTLE-KNOWN LEPIDOPTERA OF THE PHILIPPINE ISLANDS.

By W. SCHULTZE.

(From the Entomological Section, Biological Laboratory, Bureau of Science, Manila, P. I.)

RHOPHALOCERA.

NYMPHALIDÆ.

ELYMNIINÆ.

ELYMNIAS, Hübn., Verz. bek. Schmetterl. (1816), 37.

Elymnias palmifolia sp. nov. (Pl. I, fig. 1).

♂, fore wing, dark brown with a decided blue iridescence. A large, subapical, white spot, divided into 3 parts by the veins. An elongated streak between first and second median veins, slight traces of two other elongated submarginal streaks. Hind wing; pale brown near costal and inner margins, darker towards the outer margin. Between the veins, 7 yellowish-white stripes, of which there are 2 between median veins I and II. These stripes run nearly to the base of the wing where they suffuse with the general color, but they are very pronounced towards the margin. Near the outer margin, slight traces of light, wavy spots, shining through from the under side. Marginal series of interrupted, crescent-shaped, white spots in pairs between veins and confluent with cilia. Under side of wings lighter; spots corresponding as to position, but differing in size from those above. Posterior to the subapical spot, a very small white one, the streak between median veins, I and II larger than above. Between submedian and first median veins, a broad, whitish streak having a darker one through its middle and showing traces above. On the hind wing the stripes are shorter than above. On the marginal area many irregular, transverse, wavy spots.

Length of wing, ♂: 39 millimeters.

Length of wing, ♀: unknown.

Tuguegarao, Cagayan, P. I.

Time of capture: July, 1905. (Warren Williamson, collector.)

Type ♂, No. 4604, in Entomological Collection, Bureau of Science, Manila, P. I.

This species is very closely related to *Elymnias malis*, described by Semper,[1] but as he says "The observation that neither the presence nor the size of a spot, but the arrangement of the individual spots, if present, is very constant in the different species of the genera Elymnias," I feel safe in describing this species as new.

HETEROCERA.

SESIIDÆ.

ADIXOA, Hamps., Fauna of Br. Ind. Moths (1892), **1**, 198.

Adixoa tomentosa sp. nov. (Pl. I, figs. 2a male, 2b female, 2c 2d, cocoons with pupal skin.)

♀, head dark, violet-brown, front steel-blue, white at the sides; palpi white, sides blackish. Collar steel-blue, bordered in front by yellow. Thorax black with a few brownish scales and a violet sheen; a yellow stripe on the inner margin of tegulæ. Metathorax yellow; abdomen bluish-violet-black, rear margins of the second, fourth and anal segments yellow, the last slightly lighter. Posterior margin of other segments gray-brown, with a few ochraceous scales. Below, on the first abdominal segment, a white triangular spot; posterior margins white. Anal tuft black, with gray and whitish hairs, below lighter. Legs below whitish. Fore-wing, dark, iridescent, violet-brown with 1 hyaline streak in the cell, 4 beyond it, and 1 below. Discocellular yellowish, below the cell towards the base also somewhat yellowish. Cilia with a few ochraceous scales. Hind-wing hyaline, outer border with the color of the fore-wing; external cilia the same, those of the inner margin lighter to white, discocellular yellowish and brown.

♂, palpi yellow, blackish at the sides, front white, yellowish-brown on top. Posterior margin of second, fourth and anal segment yellowish. In the male, the anal tuft below is yellowish-white.

Length of wing, ♂: 8.5 millimeters.

Length of wing, ♀: 11 millimeters.

Manila, P. I.

Time of capture: June, 1905. (W. Schultze, collector.)

Type, No. 3345, in Entomological Collection, Bureau of Science, Manila, P. I.

The caterpillars live in a vine, *Paederia tomentosa* Blume, where they are easily found because of the swellings or nodules which they produce on the stems of the plant. The caterpillar makes a blackish, parchment-like cocoon compressed at both ends; from three to five cocoons are usually found together in a single nodule.

---

[1] Semper. Reisen im Arch. d. Phil. Die Schmetterl. d. Phil. Inseln. (1892), **5**, 63.

SYNTOMIDÆ.

CERYX;[1] Wllgrn. Wien. Ent. Mon. (1863), 7, 140.

Ceryx macgregori sp. nov. (Pl. I, fig. 7).

♀, dark brown, antennæ white at tips, frons with a dark spot in the center. Tops and sides of head whitish. Collar with a yellow spot at the sides. Tegulæ with a yellowish spot at the base. A yellowish, median streak on pro-, meso- and metathorax. Abdomen dark brown with 4 longitudinal series of ochraceous spots on dorsum, ventrum and sides respectively; last 2 segments without spots and lighter. Fore-wing with 5 hyaline spots, a small, elongated antemedial, 2 medial and 2 postmedial, which have a bluish sheen in certain lights. The upper medial spot is in the cell and the lower postmedial one is divided by the dark vein. Hind-wing with a large hyaline spot from the base below the cell to vein IV. Legs dark brown, coxæ with yellowish spot.

Length of wing, ♂: unknown.

Length of wing, ♀: 12 millimeters.

Montalban, Rizal, P. I.

Time of capture: February, 1906. (Charles S. Banks, collector.)

Type ♀, No. 5189, in Entomological Collection, Bureau of Science, Manila, P. I.

I take pleasure in naming this species after Mr. R. C. McGregor, ornithologist of this Bureau, who has added a large number of insects to our collection.

EUCHROMIA, Hübner, Verz. bek. Schmetterl. (1818), 121.

Euchromia elegantissima Wllgr. Eugenies Resa omkr. Jordan (1861), 360.
Var. **diffusihelvola** var. nov. (Pl. I, fig. 3).

Colors of body and markings of the wings as in the regular form of *elegantissima*. The general color of the fore-wing is brownish irrorated with yellowish scales, especially near the outer margin. Cilia dark brown.

Length of wing, ♂: 22.5 millimeters.

Length of wing, ♀: 22.5 millimeters.

Manila, P. I.

Time of capture: December, 1903. (W. Schultze, collector.)

Types ♂ and ♀, No. 448, in Entomological Collection, Bureau of Science, Manila, P. I.

ARBELIDÆ.

SQUAMICAPILLA gen. nov.

Proboscis absent; palpi very minute and porrect; antennæ of the male short, bipectinated to the tips; legs covered with long hairs, which at the tips are scale-like and on the tibiæ of the fore and hind legs very prominent. Male with a long anal tuft of hair scales.

Type: *S. arenata.*

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[1] Hampson: Cat. Lept. Phalaenae, (1898), 1, 40 (Syntomoides).

In the classification I place this new genus after the following: Arbela,[3] Moore, P. Z. S. (1879), 411.

Squamicapilla arenata sp. nov. (Pl. I, fig. 4.)

♂, palpi pale brownish; head white; collar in front whitish, at the sides dark brown. Thorax; posterior margin of tegulæ tufted with dark brown hair-scales, as is also the metathorax. Abdomen whitish; tuft of brown scales above the first segment; at the sides of the abdomen tufts of pale, yellowish hairs, the last segments (irrorated) with a few brown scales. Anal tuft very long, with its hair scales ochraceous white, but dark brown at the tips. Fore-wing pale ochraceous white, irrorated with a few brownish scales; traces of an antemedial band. At the base of the wing, below the cell, an irregular, dark brown spot and behind the cell another large, brown, trapezoidal one, sharply pronounced. Cilia with an interrupted line of brownish scales. The large scales of the fore-wing are very roughly arranged, giving the wing the appearance of being sprinkled with sand. Hind-wing white; inner margin with white hairs. Cilia broad, with traces of darker scales, as on fore-wing. Under side of the wings whitish.

Length of wing, ♂: 17 millimeters.

Length of wing, ♀: unknown.

Manila, P. I.

Time of capture: May, 1905. (Charles S. Banks, collector.)

Type, ♂, No. 2812, in Entomological Collection, Bureau of Science, Manila, P. I.

ARCTIIDÆ.

ARCTIINÆ.

PERICALLIA, Hübn., Verz. bek. Schmetterl. (1827), 182.

Pericallia integra Wlk. (Pl. I, fig. 5.)

♀, head, collar and thorax brownish-black; vertex of head yellowish-white, on top of head a dark brown spot, sides of collar and tegulæ yellowish-white. Abdomen orange above, with a blackish band on each segment, except the 2 posterior, which are black with an orange spot at the sides; abdomen below, dark brown. Fore-wing dark brown, a yellow-white band from base and below the cell nearly straight to vein II, then oblique to apex. Hind-wing orange, costal and outer margin at the apex dark brown, conjoined at middle and at the apex to larger spots; two dark brown spots at the posterior margin between veins I and IV; cilia brown, except an inner margin.

Length of wing, ♀: 20 millimeters.

Length of wing, ♂: 15 millimeters.

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[3] Hampson: Fauna of Br. Ind., Moths. (1892), 1, 315.

Quingan, Nueva Vizcaya, P. I.

Time of capture: April, 1905. (Warren Williamson, collector.)

Type ♀, No. 3986, in Entomological Collection, Bureau of Science, Manila, P. I.

The male of this species is well known and Hampson[4] gives a good description of it as does also Semper.[5] Only the female is new.

LITHOSIINÆ.

DEILEMERA, Hübn. Verz. bek. Schmetterl. (1818), 178.

Deilemera browni sp. nov. (Pl. I, fig. 6.)

♀, palpi yellowish-white, third joint brown, second brown at the sides only. Head, thorax and abdomen light yellowish, the latter slightly darker. Head with black spots on front and vertex; 2 black spots on the collar, 4 on the tegulæ and 3 on the thorax. Abdomen above with black segmental bands, laterally with 2 rows of black spots. Fore-wing creamy white. A brown, elongated, triangular area extending from the base along three-fifths of the costa. Another brown area from the base along the inner margin to the lower angle then bending upward, not quite reaching the lower angle of the cell, running along the same and bending at vein II downward towards the base, but meeting vein I shortly before the base. Outer area brown, with its inner edges dentate between the veins. The white, inner area forms roughly the letter T. Hind-wing white, with a brown streak along the costa and a very irregular band along the margins except the base of the inner margin. Below, along the inner margin from the base, a small, brownish streak.

Length of wing, ♀: 25.5 millimeters.

Length of wing, ♂: unknown.

Manila, P. I.

Time of capture: ? (Rev. Robert Brown, S. J., collector.)

Type loaned, as No. 219 (Brown Collection), to the Entomological Collection, Bureau of Science, Manila, P. I.

I take pleasure in naming this species in honor of its collector, Rev. Robert Brown, S. J.

NOCTUIDÆ.

QUADRIFINÆ.

POLYDESMA, Boised Faun. Ent. Madag., Lep. (1833), 108.

Polydesma opala Pagents. Die Lep. Fauna des Bism. Archipels, (1900), 99.

♀, palpi grayish-white with a dark brown streak at the sides and a spot on the last joint. Head, thorax and abdomen grayish-white; a few darker scales in the middle of thorax; anal tuft reddish-brown. Fore and mid-tarsi and hind tibiæ and tarsi with dark brown spots. Fore-wing; basal area grayish-white, reaching at the inner margin from the base to lower outer angle, then from the angle an oblique irregular line to the middle of costa. A large, irregular triangular suffused dark brown spot at the base and upper angle of the wing along the costa. Outer area of the wing suffused brown, a large white apical and a smaller, indistinct subapical spot. Below the apical spot another dark brown one; traces of indistinct dark brown and whitish, submarginal, zigzag lines. Cilia at the apex whitish, then pale brown with darker spots, and again at the inner margin whitish. Hind-wing fuscous, especially near outer margin, with an indistinct postmedial and submarginal band. A small, iridescent streak along the inner margin. Color of the cilia the same as on fore-wing but lighter. Below; fore-wing, suffused fuscous with traces of a postmedial and submarginal band; hind-wing with a dark spot at the end of the cell and the postmedial and submarginal bands more distinct as above.

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[4] Hampson: Cat. of the Lept. Phal. (1901), 3, 359.

[5] Semper, Reisen auf den Phil., Die Schm. d. Phil. Inseln (1892), 6, 486.

♂; collar more ochraceous, thorax with dark, grayish-brown hairs. Fore-wing; the brown basal spot not so dark as in the female, with a whitish marking inside of it and its outer edges continued with a suffused, dark brown, irregular, antemedial band. The white area very much suffused with traces of brownish spots. The white, apical and dark brown, subapical spots prominent.

Only the male of this species is new.

Length of wing, ♂: 15 millimeters.

Length of wing, ♀: 15.5 millimeters.

Manila, P. I.

Time of capture: August, 1904. (Charles S. Banks and Rev. Robert Brown, S. J., collectors.)

Type ♂, No. 5711, in Entomological Collection, Bureau of Science, Manila, P. I.

REMEGIA,[a] Guen. Noct. (1852), iii, 312.

Remigia intextilia sp. nov. (Pl. I, fig. 8.)

♂, head, thorax and abdomen gray-brown, some dark speckles at the tegulæ. General color of the wings light gray-brown; fore-wing with 2 dark spots in the cell and a large prominent one at the end of it. Three very indistinct, dark, antemedial zigzag lines and a medial line from below the cell to the inner margin. A broad, irregular, slate-gray, postmedial band from the apex reaching the inner margin before the angle. An indistinct, white marking at the apex and a submarginal series of dark specks. Hind-wing with distinct, antemedial band nearly straight, suffused, indistinct, medial bands which are combined with the irregular, postmedial band. Some blackish specks at the medial line and a series of submarginal specks as on the fore-wing. The hair fringe at the inner margin pale. On both wings a fine, pale, marginal line. Under side of the wings, the markings are more distinct; fore-wing with a black spot in the cell and one at the end of it. A distinct medial line and postmedial band. Hind-wing with a dark spot near the base, an antemedial, distinct medial and a postmedial, zigzag line. The area between medial and postmedial lines is darker, forming a band.

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[a] Hampson: Fauna of Br. Ind., Moths (1892), 2, 527, Sec. III (Remigia).

Length of wing, ♂: 24 millimeters.

Length of wing, ♀: unknown.

Manila, P. I.

Time of capture: December, 1905. (Charles S. Banks, collector.)

Type ♂, No. 4808, in Entomological Collection, Bureau of Science, Manila, P. I.

CRUSISETA gen. nov.

♂, palpi with the second joint thickened and reaching vertex of head, the third short and blunt; antennæ bipectinated, the pectinations short. Thorax clothed with long hairs. Abdomen slender, dorsally with hair tufts to fourth segment, then smoothly scaled and an anal tuft of moderate length. Fore and mid femur and tibia hairy, hind tibia and tarsi with very long tufts of hair. Mid and hind tibiæ with spines. Fore-wing; costa nearly straight, slightly curved towards apex; apex slightly angled, outer margin slightly curved, on the inner margin near the base a moderate tuft of erect hair scales. Hind-wing with apex slightly rounded, inner margin fringed with long hair.

Type: *C. basipuncta.*

In classification I place this new genus after the genus Crithote,[7] Wlk. Jour. Linn. Soc. (1864), **7**, 182.

Crusiseta basipuncta sp. nov. (Pl. I, fig. 9.)

Palpi dark brown; head, collar and anterior half of thorax dark brown, changing to fuscous on the metathorax. Abdomen fuscous. Legs, except the tarsi, dark brown. Fore-wing with a straight, antemedial, yellowish line, oblique from the inner margin near the base to subcosta. Base and area along the costa purple-gray. A distinct, dark brown spot near the base and upper angle of the wing. Outer area dark brown, growing lighter towards the outer margin, which is purplish-gray. The tuft of hair scales at the inner margin dark brown. Hind-wing fuscous.

Length of wing, ♂: 16 millimeters.

Length of wing, ♀: unknown.

Manila, P. I.

Time of capture: August, 1905. (Charles S. Banks, collector.)

Type ♂, No. 3984, in Entomological Collection, Bureau of Science, Manila, P. I.

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[7] Hampson: Fauna of Br. Ind., Moths (1894), **2**, 541.

GEOMETRIDÆ.

BOARMINÆ.

MILIONIA, Wlk., Cat. (1854), 2, 364.

Milionia pretiosa sp. nov. (Pl. I, fig. 10.)

♀, palpi and front, pale brown, shot with light blue, the sides of head whitish. Collar, thorax, abdomen and legs pale brown. A triangular, ochraceous spot at base of thorax; collar, tegulae, and coxae being especially shot with light blue. Fore-wing light ocherous, the apical half to lower angle of the wing, dark brown. An interrupted medial band from costa reaching the inner margin before the angle. At the base of wing an irregular spot, also dark brown. Hind-wing orange, a large, pale brown spot between costa and vein, which is covered by fore-wing. Another large dark brown spot between veins II and V; at the outer margin beginning on the upper angle a large, irregular spot; three round spots also along the outer margin at veins III, IV and V; the last one being the largest. There are some traces of pale, brownish spots along the veins next to the inner margin.

Length of wing, ♀: 25 millimeters.

Length of wing, ♂: unknown.

Manila, P. I.

Time of capture: July, 1905. (Alice and Fritz Worcester, collectors.)

Type ♀, No. 3591, in Entomological Collection, Bureau of Science, Manila, P. I.

PYRALIDÆ.

SCHOENOBIINÆ.

SCIRPOPHAGA, Treitschke, Schmetterl. Eur. (1832), 9, 1, 55.

Scirpophaga virginia sp. nov.

Head, thorax, rear edges of abdomen, anal tuft and wings snow-white. The under side of the fore-wings, in the male sex, except the cilia, is grayish, as are fore-legs, and in both sexes the mid tibiæ with gray spots.

Length of wing, ♂: 7.5 millimeters.

Length of wing, ♀: 8.5 millimeters.

Manila, P. I.

Time of capture: September and October, 1905. (G. L. Araneta, collector.)

Type ♂, No. 4466, and ♀, No. 4351, in Entomological Collection, Bureau of Science, Manila, P. I.

This species is closely related to *Scirpophaga gilviberbis* Zell.

Pyralinæ.

VITESSA, Moore, Lep., E. I. C. (1858), 299.

Vitessa splendida sp. nov. (Pl. I, fig. 11.)

♀, head yellow, third joint of palpi gray; collar and tegulæ dark, metallic-gray, bordered by yellow. Thorax yellow, growing lighter towards metathorax; at the middle of thorax two confluent spots of which the posterior one is the smaller. Abdominal segments banded dark gray and white; anal tuft orange-yellow. Legs gray, fore-coxæ yellowish, middle coxæ and middle and hind femora white below. Hind tibiæ banded with white. Fore-wing dark, metallic-gray. A yellowish, basal, subtriangular spot with the basal edge excised circularly. The spot extending from costa nearly to posterior margin and having its outer side parallel with the bases of 2 white, subtriangular, antemedial spots, the lower of which is the larger. Two postmedial, white spots, one subtriangular and subcostal, the other trifid[8] and subtriangular. The outer third of the wing longitudinally striated with a series of ten nearly parallel, whitish lines. Hind-wing white; outer half and a stripe along the costa dark, violet-gray. Cilia white.

Length of wing, ♀: 21 millimeters.

Length of wing, ♂: unknown.

Maao, Negros Occidental, P. I.

Time of capture: November, 1902. (Charles S. Banks, collector.)

Type ♀; No. 4567, in Entomological Collection, Bureau of Science, Manila, P. I.

This species is nearly related to *Vitessa suradeva*, Moore, Lep., E. I. C. P. 299, Pl. VII, fig. 7.

Pyraustinæ.

PYRAUSTA, Schrank, Fauna Boica (1812), 2, 163.

PYRAUSTA, Hampson: Fauna of Br. Ind., Moths, (1896), 4, 429.

Pyrausta vastatrix sp. nov. (Pl. I, fig. 12.)

♀, palpi dark ochraceous, white below. Thorax and abdomen ochraceous, the last abdominal segments lighter. Fore-wing, ochraceous yellow with a reddish-ochraceous, excurved, antemedial, and a prominent postmedial zigzag line. A small speck in the cell and another at the discocellular, extending towards the postmedial line. The marginal and costal areas also reddish-ochraceous. Hind-wing pale, darker towards outer margin. A fine, brownish line at the outer margin. The fore-wing of the male somewhat darker, espcially the area between the ante- and postmedial lines, suffused reddish ochraceous.

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[8] This is not well shown on the plate. The markings should be closer together.

Length of wing, ♀: 15.5 millimeters.

Length of wing, ♂: 11.5 millimeters.

Manila, P. I.

Time of capture: March, 1904. (Charles S. Banks and W. Schultze, collectors.)

Type ♂ and ♀, No. 1365, in Entomological Collection, Bureau of Science, Manila, P. I.

This species is very abundant in the vicinity of Manila, the caterpillar living in corn.

Pyrausta matuta sp. nov. (Pl. I, fig. 13.)

♀, palpi brown, white below; collar, thorax and abdomen yellowish. rear margin of abdominal segments whitish. General color of wings yellow. Fore-wing with a dark ochraceous antemedial, and a medial line, excurved in the middle and below the cell enlarged to a spot. Two postmedial lines of which the one next the outer margin is much excurved and runs together with the inner one at the inner margin. All these lines are very prominent. At the middle of the costa a small, brown streak. Hind-wing with a medial line, which is enlarged to a spot below the cell. Two postmedial lines, the inner one nearly parallel to the medial line; the outer one much excurved, meeting the inner one near the hind margin. Both wings with a strongly marked, brownish line at the base of ciliæ which are ochraceous. Wings below lighter. Fore femur and tibia light brown, first joint of tarsus light brown with the base and apex white. Mid femur light brown, all other parts, including hind legs, yellowish white.

Length of wing, ♀: 13.5 millimeters.

Length of wing, ♂: 10.5 millimeters.

Manila, P. I.

Time of capture: November, 1905. (P. G. Woolley and G. L. Araneta, collectors.)

Type ♂ and ♀, No. 4665, in Entomological Collection, Bureau of Science, Manila, P. I.

TINEIDÆ.

HYPONOMENTINÆ.

Psecadia delicata sp. nov. (Pl. I, fig. 14.)

♂, antenna gray with a black spot at the base. Head, thorax and metathorax very light gray; palpi, the third joint black banded. Two black spots on the collar, a small one at the anterior part of the tegulæ and five black spots on the thorax. Abdomen, dark gray below, and anal tuft lighter. Fore legs dark gray, the other lighter, middle tibiæ with a dark spot, mid and hind tarsi dark gray. Fore-wing light gray with

15 black spots, of which 3 are near the base; 2 next and parallel to the outer margin, the others being scattered irregularly over the discal area of the wing. Hind-wing darker gray, with the cilia lighter, especially on the inner margin. Under side of wings dark, smoky gray.

Length of wing, ♂: 8.5 millimeters.

Length of wing, ♀: unknown.

Manila, P. I.

Time of capture: August, 1905. (Charles S. Banks, collector.)

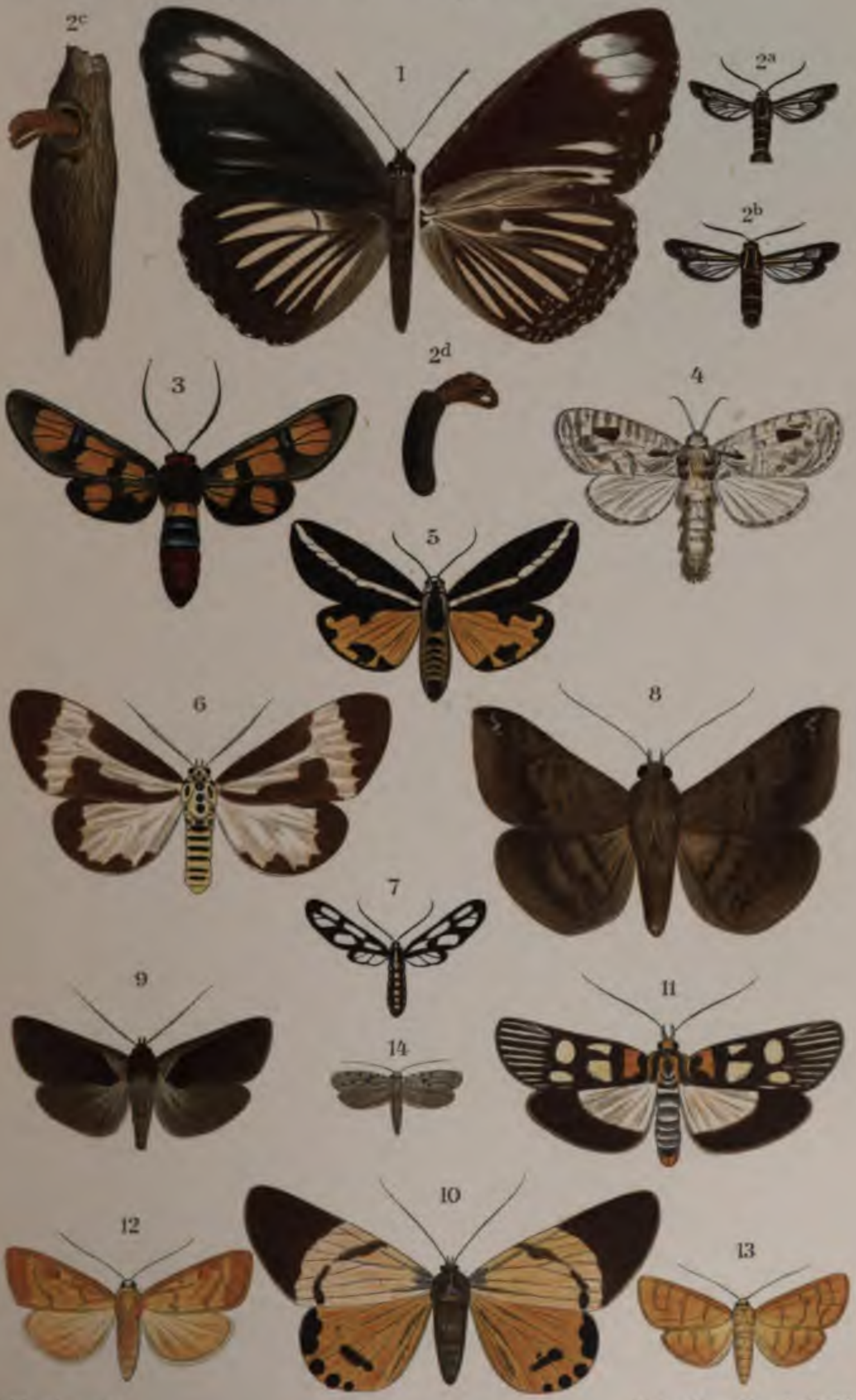
Type ♂, No. 4186, in Entomological Collection, Bureau of Science, Manila, P. I.

ILLUSTRATIONS.

PLATE I.

FIG. 1. *Elymnias palmifolia* Schultze ♂.
2 a–d. *Adixoa tomentosa* Schultze ♂, ♀ and cocoons with pupal skin.
3. *Euchromia elegantissima* var. *diffusihelvola* Schultze ♀.
4. *Squamicapilla arenata* Schultze ♂.
5. *Pericallia integra* Schultze ♀.
6. *Deilemera browni* Schultze ♀.
7. *Ceryx macgregori* Schultze ♀.
8. *Remigia intextilia* Schultze ♂.
9. *Crusiseta basipuncta* Schultze ♂.
10. *Milionia pretiosa* Schultze ♀.
11. *Vitessa splendida* Schultze ♀.
12. *Pyrausta vastatrix* Schultze ♀.
13. *Pyrausta matuta* Schultze ♀.
14. *Psecadia delicata* Schultze ♂.

W. Schultze: New Lepidoptera of the Philippine Islands.



W. Schultze pinx.

Lith. Anst. v. Werner & Winter, Frankfurt a/M.

EDITORIAL.

The PHILIPPINE JOURNAL OF SCIENCE will begin a series of short editorial articles in the first number of Volume III, and will continue this policy in each succeeding number. These articles will consist of shorter notes concerning the work which is being carried on in the Philippines that otherwise would not be published, but which may be of interest to the readers of the journal. The body of the JOURNAL will be reserved for the longer papers embodying extended investigations, as heretofore.

PAUL C. FREER.

PHILIPPINE ARROW POISONS.

Many of the uncivilized and semicivilized tribes of the Philippines use poisoned arrows, principally for killing game. It is exceedingly difficult to discover the nature of the poisons which are used, as the wild man is of a very suspicious nature and will give misleading statements to anyone who endeavors to ascertain what plants he employs in their preparation. Many tribes claim the knowledge of the means of poisoning arrows to be a secret held only by the old men. Thus, Dr. Foxworthy, of this Bureau, after an extensive visit among the Negritos of Bataan Province, was told by these little people that they poisoned their arrows by using the bark and sap of two trees, one of which is *Diospyrus canomoi* and the other a tree called *bicag*. The latter was said to be very poisonous, but it was not identified. The Negritos in common with many other Filipino tribes, believe in the exceedingly deadly nature of *Diospyrus conomoi,* but the specimens of this plant which have been brought into the laboratory have been only very moderately toxic.[1] About two years ago, Commissioner Worcester succeeded in obtaining a small amount of arrow poison from the northern part of Mindoro near Bulalacao, evidently the sap of a tree. The sap was a milky liquid, the consistency of cream, specific gravity 1.065 at 15°. It had an exceedingly bitter taste and a high viscosity. The odor resembled that of sour bread dough, a slight fermentation had set in, the reaction was slightly acid. A quantity of a rubber-like substance was coagulated from the solution when it was heated with a little dilute acid. The arrow poison gives a very slight precipitate with Mayer's solution, but an abundant one with phosphomolybdic acid. These reactions indicated the presence of a glucoside rather than of an alkaloïd, which suspicion was strengthened by the reduction of Fehling's solution by arrow poison which had been boiled with dilute acids. The milky sap was extracted with boiling benzol for two days. The extract was evaporated to dryness and the residue treated with boiling water. Basic lead acetate was added to the aqueous solution, it was then filtered and the excess of lead was removed from the filtrate by hydrogen sulphide. The filtrate was neutralized with calcium hydroxide and evaporated to dryness, the residue being extracted with hot alcohol, from which on cooling a small amount of substance separated in the form of small, crystalline, pearly plates. These crystals give an intense, golden-yellow color with concentrated sulphuric acid containing a trace of ferric chloride, which soon passes into a yellowish-red color. The lethal dose of these crystals in guinea pigs was found to be 0.00003 to 0.00005 gram per 100 grams of animal. As these reactions correspond very closely with those of the glucoside *antiarin* from *Antiaris toxicara* it was immediately suspected that the arrow poison was from this tree, but as this tree had never been found in the Islands, a Filipino was sent to this part of Mindoro to obtain more of the poison together with botanical material. A quantity of this as well as of the bark was procured, but no more of the poisonous sap. The tree was positively identified as *Antiaris toxicara* Lichen, identical with the famous poison Upas tree of Java. The bark of the tree is quite fibrous and the extract, after being boiled with dilute acids, has a peculiar and very distinctive odor like that of the sap when treated in the same manner. Six hundred grams of finely ground bark were boiled with water for twelve hours, the whole was then filtered, the adhering liquid pressed out and the solution evaporated to 1 kilo. It was now treated with basic lead acetate, etc., as in the former procedure with the sap of the tree and thus a small amount of crystalline material was obtained which with concentrated sulphuric acïd containing a trace of ferric chloride gave a golden-yellow color, later passing into red (Kiliani). With one cubic centimeter of 3 per cent sodium carbonate solution to which three drops of a concentrated solution of picric acid had been added it gave, on heating, an orange color which on continued heating became more and more red (Wefers-Betinck). The bark also gives this last test very strongly. To obtain an idea of the quantity of antiarin in the bark of this tree, 100 grams of finely divided bark were extracted hot with 500 cubic centimeters of water and the filtered extract concentrated to

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[1] Bacon, R. F.: *This Journal* (1906), 1, 1028.

100 cubic centimeters. This extract was injected intraperitoneally into guinea pigs with the following results:

Number.	Weight of guinea pig.	Extract.	Extract per 100 grams guinea pig.	Remarks.
	Grams.	*cc.*	*cc.*	
1	570	5.8	1	Dead in 1 hour.
2	570	2.75	.5	Dead in 20 hours.
3	155	.40	.25	Dead in 8 hours.
4	160	.40	.25	Dead in 8 hours.
5	650	1.3	.20	Dead in 30 hours.
6	440	.90	.20	Dead in 27 hours.
7	205	.40	.20	Dead in 3 hours.
8	520	.70	.12	Survived.
9	720	.50	.12	Do.

Guinea pigs 8 and 9 showed almost no effects from the injection, while all the others developed violent symptoms soon after dose was given.

These experiments indicate that in 100 grams of bark there is 0.025 gram antiarin, as against 3.2 per cent of the glucoside found in the sap of the tree, if we can judge from the physiological experiments. The minimum fatal dose of this arrow-poison sap was 0.00156 cubic centimeter for 100 grams of animal, the calculation being based on a minimum fatal dose of antiarin of 0.00005 gram per 100 grams of animal.

The symptoms of antiarin poisoning have been well described by Seligmann.[2] The *Antiaris* sap loses its poisonous properties on boiling with dilute acids, being split up into a sugar called by Kiliam [3] antiarose and an indifferent body, antiarol, which seems to be identical with tetraoxybenzol trimethylether.[4] Many animals poisoned with antiarin were watched for twenty-four hours, but none recovered, as is often the case with curare arrow poisoning.

Other poisoned arrows have been obtained by members of this Bureau from the Tagbanuas at San Antonio Bay near the south end of Palawan. These arrows are used in blow guns and are 32 to 33 centimeters in length, being made of bamboo. Some of the arrows obtained have bone barbs fastened on the bamboo shaft with hemp fiber. All have a pith top to fit into the cane blow gun. The barb as a rule is 6 centimeters, the shaft 26 centimeters long and 3 to 3.5 millimeters in diameter. The poison is placed on the barb and shaft for a distance usually of about 5 centimeters and the amount of poison on each arrow is from 0.2 to 0.5 gram. This arrow poison has a consistency like rubber and it resembles in this respect the dried sap of *Antiaris toxicara;* the solution boiled with dilute acids gives the same peculiar and characteristic odor obtained from the antiaris sap under the same conditions. I was not able to isolate any antiarin from the small amount of material available, but could obtain color reactions which correspond with those from antiarin and also with those of the alkaloïds of *dita* bark. It is probable that, if the alkaloïds of *dita* bark are present, they are an unimportant constituent of the poison. The physiological action of this poison reminds me very much of that shown by antiarin as is evidenced by the following:

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[2] *Brit. Med. Journ.* (1903), **1**, 1129.

[3] *Arch. d. Pharm.* (1896), **234**, 438.

[4] Graebe and Suter, *Ann. Chem.* (*Liebig*) (1905), **340**, 220.

Guinea pig, weight 450 grams, 0.003 gram arrow poison inserted subcutaneously. In two minutes there is an excitement stage of the action; in four, a marked decrease in the rate of respiration is noted and the breathing labored. This stage is very rapidly followed by convulsive spasms and lack of muscular coördination. These convulsive spasms of the diaphragm and abdominal muscles last each about one second. This condition is soon followed by general convulsions, retraction of the head and extension of the fore and hind legs, the muscles being rigid for from 1 to 5 seconds. Each contraction of the muscles is explosive in character. Breathing becomes more and more difficult, the pupils are dilated, and the animal dies apparently of asphyxia. For several minutes after breathing has stopped there are muscular twitchings and irregular contractions of the heart, which finally stops in diastole. Death occurs in 8 minutes. There is no local irritation at the point of inoculation.

This experiment is typical of many others made on this powerful poison. It was found that 0.001 gram of the arrow poison will kill 500 grams of animal in 30 minutes, so that there is sufficient poison on one of these small arrows to kill from 100 to 250 kilograms of animal in half an hour.

Other animal poisons in the Philippines are prepared from fermented pineapple leaves, from *Sunasia Amori* Blanco, from *Lophopetalum toxicum* Loher and from *Strophanthus Cumingii* DC. These have not yet been investigated.

One case of poisoning from Dolores, Abra, came to this laboratory in which the poison used, a pounded fibrous bark, was identified as that of *Antiaris*, showing that the tree is probably not local to Mindoro and will doubtless be found in other parts of the Archipelago.

RAYMOND F. BACON.

FOOD AND DRUG INSPECTION.

The "Food and Drugs Act" of the Philippine Commission, passed May 18, 1907, is uniform with the United States act of June 30, 1906, in all of its provisions except those relating to the enforcement of the law by the courts and other officials of the Philippine Islands. The

Insular Collector of Customs, the Director of Health, and the Collector of Internal Revenue are authorized to make uniform rules and regulations subject to the approval of the Secretary of the Interior of the Philippine Islands for the enforcement of the law, and the Bureau of Science is directed to carry on all examinations of samples submitted by the three officials in whom the active enforcement of the law rests. The work of actively enforcing the law was commenced in the month of August, 1907, by the inspection of foods and drugs passing through the custom-house of the port of Manila. Later, the collection of samples was extended to other ports of entry of the Philippine Islands. During the first six months of the enforcement of the law, August, 1907, to February, 1908, over four hundred samples of foods and drugs were examined by this Bureau. These samples will be segregated into their respective classes and the analyses summarized from time to time. The butters, cheeses, and hams are represented as follows:

Butters.—Number of samples, 30: Australia, 14; Denmark, 3; France, 2; Germany, 2; Holland, 8; United States, 1. The analyses showed 9 to be imitations, 12 to contain a boron compound, and 9 legal.

Cheeses.—Number of samples, 24; England, 1; France, 3; Germany, 2; Holland, 15; Switzerland, 2; native, 1. The classes represented are Brie, cottage, Gruyère, Limburger, Roquefort, Stilton and the Dutch varieties. The analyses showed that 10 samples were not according to the standards and were probably made from skimmed milk. Fourteen were found to be legal.

Hams.—Number of samples, 30: Australia, 1; China, 3; England, 17; Japan, 1; United States, 8. The analyses showed 26 to contain nitrates and 7 a compound of boron.

H. D. GIBBS.

PURIFICATION OF COCONUT OIL.

Coconut oil, as it is expressed from sun or grilled dried copra, always contains a quantity of impurities—organic coloring matter, albuminoid bodies and a certain characteristic odor, all of which are objectionable for particular purposes for which the oil is otherwise well suited. While it is entirely possible to produce a pure oil directly from the nuts if special precaution in curing them is taken, the demand for highly refined oil does not seem to warrant the introduction of modern mechanical methods of desiccation at the present time, hence the numerous patents which are taken out from time to time and the frequent notices in the literature of new or improved processes for the production of pure coconut oil, refer to some subsequent chemical treatment of the commercially expressed oil itself. Clarification by filtration, subsidence or heating with or without the addition of coagulants is simple and economical of application and, as generally practiced, removes all of the suspended foreign matter and most of the soluble impurities, producing a perfectly clear, light, amber oil of sufficient purity for soap stock, but it falls short of being completely free from odor and color. Therefore, further refining constitutes the only known means of producing an odorless and colorless product suitable for alimental or cosmetic purposes. The removal of the last traces of odor and color from coconut oil presents many difficulties in the way of subsequent clarification and risk of loss of oil and the methods of procedure are necessarily limited to the use of such chemical reagents as are harmless or are easily removed. In general, refining processes may be conveniently divided into (1) acid and (2) alkaline treatments, the former has not proved applicable for the production of oils for edible, cosmetic or lubricating purposes, because of the poisonous nature and otherwise harmful action of mineral acids. The alkaline process makes use of the hydrates or carbonates of the fixed alkalies, ammonia, caustic lime or magnesia, with or without the aid of heat. The efficiency of an alkaline treatment depends upon incomplete saponification, whereby the free, volatile, fatty acids, which are responsible to a large measure for the characteristic odor of coconut oil, are first neutralized and precipitated as a salt of whichever alkali is employed. If the alkali be added in excess of the amount necessary to neutralize the free acids and the oil is steamed or otherwise heated, then the neutral glycerides—that is, the oil itself—suffers partial decomposition and goes to augment the amount of soaps formed. Therefore, unless any alkaline treatment of a vegetable oil is carefully regulated, both as regards the amount of alkali used and the temperature employed, low yields of purified oil are obtained. All of the residues or "foots" go to form soap stock, hence the advisability is apparent of employing this process in conjunction with a market for the by-product. The main points to note in connection with refining by means of alkalies are, first, the minimum quantity of alkali necessary to effect the purification and, second, the right concentration of caustic lye which is unfavorable to the formation of emulsions. The minimum quantity of alkali can be determined accurately by testing the acidity of a small sample of the oil to be refined, or by the cut and dried methods of practical experience.

Ordinary commercial grades of coconut oil collected on the Manila market contain from 1 to 10 per cent of free fatty acids calculated as oleïc acid, and these percentages require approximately 0.15 to 1.5 parts, respectively, of caustic soda per 100 parts of oil. The caustic soda may be added to the oil either in the solid state with subsequent addition of water, or better, in the form of a caustic liquor previously prepared. The stronger the caustic liquor used the less the tendency to emulsion formation and the more rapid and complete the action, if proper mechanical devices for thoroughly mixing a strong lye with the oil are used. If, after the addition of the caustic the oil is gradually heated to the boiling point of water, the soap separates in a granular condition and is easily removed by filtration or subsidence. The oil may now be steamed and washed with hot water until it is perfectly clear and neutral, and if the above treatment with caustic liquor and the subsequent steaming are properly conducted, the resulting oil will be found perfectly free from the well defined odor of the original oil and to possess the bland, fatty odor of pure melted lard.

Coconut oil is also considerably lightened in color by the above treatment, but in no sense can it be considered as a colorless oil. To remove the last traces of coloring matter from a vegetable oil is much more difficult than the destruction of the rancid odor, and in order to accomplish this completely it is necessary to subject the refined oil to some mild bleaching action which does not introduce harmful ingredients which would be difficult of subsequent removal. Of the many well-known methods of bleaching proposed for general use, hydrogen peroxide seems to be most favorable in this regard as it is easy of application and at its present price is not prohibitive. Sufficient dilute alkali should be added to neutralize any mineral acid it may contain and a slight excess favors the action of this reagent, at the same time having no saponifying action. Next in order of suitability is a dilute solution of chloride of lime slightly acidified with acetic acid. If the addition of acid and the temperature of the bleaching are carefully controlled, the chance of injury to the oil by free chlorine is a minimum and the result is a pure, water-white product.

GEORGE F. RICHMOND.

Harry M. Ickis, E. M.

DIVISION OF MINES
BUREAU OF SCIENCE

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PHILIPPINE TERPENES AND ESSENTIAL OILS, I.

By RAYMOND F. BACON.

(*From the Chemical Division, Bureau of Science, Manila, P. I.*)

INTRODUCTION.

The Philippines, like all tropical countries, are very rich in plants producing resins, terpenes and essential oils, and this laboratory has been engaged in studying certain of these for the past three years. The identification of the various products from Manila *elemi* and a study of the physical constants of the terpenes derived therefrom have already been reported on by Clover[1] who has also recorded a few notes on resins containing sesquiterpenes.[2] It was shown by Clover that Manila *elemi* on distillation yields 15 to 20 per cent of terpenes, and that by selecting resins from individual trees it was possible to obtain a supply of these in a pure state, those most frequently found being *d*-limonene and *d*-phellandrene. The resin remaining after the terpene is distilled off is a dark, amber colored, semisolid product, readily soluble in organic solvents, and experiments show beyond doubt that it would be a satisfactory raw material for preparing varnishes. The volatile oils derived from Manila *elemi* are valuable for many purposes for which ordinary turpentine is used. However, it was thought that chemical studies on these terpenes might develop more valuable uses to which they could be applied, apart from the large scientific interest which their study possesses; thus a broader applicability of these oils might result and the whole Philippine resin industry be advanced.

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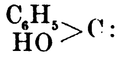
[1] *This Journ., Sec. A., Gen. Sci.* (1907), **2**, 1.

[2] *Ibid.* **1**, 191. A large amount of experimental material has since been accumulated by this Bureau on the subject of some of the native resins.

The terpenes present a difficult field for investigation. The usual methods of organic synthesis often fail in working with them and general methods of passing from one class of compounds to another are not only not well developed, but they frequently fail even with the greatest precautions. The terpenes, being, hydrocyclic bodies, partially unsaturated, are very sensitive to reactions which would present conditions where polymerization is possible, while oxidation and many other reactions often involve their complete destruction or the formation of noncrystalline derivatives and smears. Nevertheless, it appears as if an intimate connection between the terpenes and the essential oils and perfume substances, as well as between them and the plant alkaloids exists structurally, and therefore the investigation of synthetic methods among the terpenes becomes of vital importance. The great need is to discover methods generally applicable of passing smoothly from the terpenes to their derivatives and the means of obtaining the latter in the pure state. The Grignard reaction, which in the last few years has developed so many other fields of organic chemistry, naturally suggests itself, for the hydrogen halides of the terpenes are in almost all cases compounds easily prepared. It was therefore decided in this laboratory to take up the study of the Grignard reaction in its application to the terpene series and although the work is not by any means completed, the results obtained seem to be so promising that it was deemed advisable to publish this preliminary notice so as to reserve the field.

It has definitely been proved that limonene hydrochloride reacts with magnesium in the presence of absolute ether to form a magnesium-halogen compound, and that the latter, when decomposed by water, gives a hydrocarbon $C_{10}H_{18}$, this takes up hydrogen chloride in the cold and, after the action of magnesium and then of water, gives $C_{10}H_{20}$. The reaction of benzaldehyde on the mixed compound of ethyl ether and magnesium hydro-limonene chloride is extraordinary; the carbinol which is to be expected, is not formed, but instead the benzaldehyde behaves as if it contained hydroxyl, decomposing the Grignard body in the same manner as water or an alcohol would. It is at first thought very surprising that benzaldehyde should be capable of reacting as if it possessed a tautomeric form  $\begin{matrix}C_6H_5\\HO\end{matrix}\!\!>C:$ However, Freer[3] showed some years ago that aldehydes react with sodium as if they contained hydroxyl groups, and Nef[4] and his students have recently proved that aldehydes, in many cases, do assume the enol form before reacting, so that an equilibrium between enol and keto structure is to be expected in these bodies. It is more difficult to believe in such a structure in the case of benzaldehyde, in which body, if we refer to our ordinary conceptions of organic chemistry, we will need to assume that a minute trace of the methylene derivative is always present. However that may be, it is a fact that all substances capable of assuming the enol and keto types respectively act with the Grignard reagent so far as they have been studied, as if composed of the former, thus, acetoacetic ester, urea, thiourea and the amides, etc., all behave toward alkyl magnesium halides as if they contained hydroxyl groups.

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[3] *Am. Chem. Jour.* (1896), **18**, 552.

[4] *Ann. Chem.* (*Liebig*) (1907), **357**, 258.

EXPERIMENTAL.

The action upon magnesium of limonene hydrochloride dissolved in absolute ether, is not vigorous, or even fairly complete unless certain rigid conditions are met, but if these are adhered to the reaction takes place smoothly and very rapidly to practical completion. Many experiments were undertaken to obtain the best conditions. The limonene hydrochloride must be as pure as possible and in most of my experiments it was twice refractioned *in vacuo;* the ether also must be very pure and absolutely dry. The best results were obtained by the usual procedure of removing all soluble impurities by shaking with small portions of water, then drying the reagent over calcium chloride, distilling from sodium wire and finally keeping the ether over sodium wire in a bottle protected by a tube filled with soda lime. The Grignard body which is produced absorbs oxygen very rapidly, and so in most instances my reactions were conducted in an atmosphere of dry hydrogen. It is desirable to have the magnesium as pure as possible, although satisfactory results may be obtained with magnesium which is not strictly so if it is properly treated beforehand. The persistency with which limonene hydrochloride refuses to react unless all conditions are strictly met is shown by one experiment in which a mixture of limonene hydrochloride, magnesium and ether was placed at ordinary temperature without reaction and finally heated in a sealed tube to 120° to 130° for twenty hours without any change.

The following experiments gave a different result:

Experiment 1.—The limonene was obtained from orange peel oil which was twice refractioned and the terpene then distilled over sodium; its boiling point was 174° to 176° at atmospheric pressure. Specific gravity, $\frac{30^\circ}{4^\circ}=0.8350$; $N\frac{30^\circ}{D}=1.4670$; $A\frac{30^\circ}{D}=110.7$. One hundred and fifty grams of this product were dissolved in an equal volume of dry carbon bisulphide and dry hydrogen chloride was passed for two working days into the liquid, which was kept in a freezing mixture. The product was then washed with water and dilute alkali, dried over calcium chloride, the carbon bisulphide distilled and the product fractioned *in vacuo.* One hundred and ten grams of limonene hydrochloride of a boiling point of 105° to 107° at 20 millimeters were obtained. Specific gravity, $\frac{30^\circ}{4^\circ}=0.9703$; $N\frac{30^\circ}{D}=1.4770$; $A\frac{30^\circ}{D}=73.1^\circ$. The following was the analysis:

	Found (per cent).	Calculated for $C_{10}H_{17}Cl$ (per cent).
Cl	20.1	20.3

The Grignard reaction was conducted in a 400 cubic centimeter bromine flask, in an atmosphere of dry hydrogen. One hundred and fifty cubic centimeters of absolute ether and 7 grams of magnesium filings were placed therein and the reaction was begun with a few drops of ethyl bromide, 45 grams of limonene hydrochloride were then added, whereupon the reaction continued vigorously; after it was completed the product was poured over cracked ice and dilute sulphuric acid carefully added. The ethereal layer was separated, dried over calcium chloride, the ether distilled and the product finally fractioned *in vacuo* with the following results:

Fraction No. 1: B. P. 100° to 102° at 65 millimeters; 25 grams, chlorine free.

Fraction No. 2: B. P. 102° to 110° at 60 millimeters; 5 grams, containing a trace of chlorine.

Fraction No. 3: The residue in the distilling flask, 3 grams, contains a small amount of chlorine.

Fraction No. 1, was redistilled over sodium at ordinary pressure and then yielded 23 grams of an oil boiling between 174° and 176°, with following constants: Specific gravity, $\frac{30^\circ}{4^\circ}=0.8257$; $N\frac{30^\circ}{D}=1.4585$; $A\frac{30^\circ}{D}=90.3$.

Fractions Nos. 2 and 3 were united and fractioned over sodium, they gave 3 grams of an oil passing over between 180° and 210°, containing no chlorine. The low boiling portion, No. 1, which posseses an ether-like odor, was again distilled at ordinary pressure in an atmosphere of carbon dioxide and 8 grams from the middle portion were taken for analysis. The constants of this fraction were: $N\frac{30^\circ}{D}=1.4565$; the molecular refraction was $M=45.5$ calculated for $C_{10}H_{18}|^{=}=45.3$.

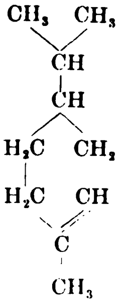
(1) 0.2420 gram substance gave 0.7720 gram CO_2 and 0.2820 gram H_2O.

(2) 0.1621 gram substance gave 0.5160 gram CO_2 and 0.1902 gram H_2O.

	Found (per cent).		Calculated (per cent).	
	(1)	(2)	$C_{10}H_{18}$	$C_{10}H_{16}$
C	86.99	86.85	86.96	88.2
H	12.98	13.07	13.04	11.8

The result leaves little doubt but that the hydrocarbon has the formula $C_{10}H_{18}$, but to assure greater certainty it was decided to convert it into the completely reduced substance, $C_{10}H_{20}$.

This hydrocarbon $C_{10}H_{18}$, is probably the dihydro-limonene:



and identical with the Δ^1 para menthene which Semmler[5] obtained by the reduction of limonene hydrochloride with sodium and alcohol at a temperature not higher than 10°. Semmler's dihydro-limonene had a boiling point of 173° to 174°; specific gravity, 20°=0.829; $N_D=1.463$; Pol.= +40, while the same hydrocarbon prepared from phellandrene hydrochloride by reduction with sodium and amyl alcohol has a boiling point of 171° to 172°; specific gravity, 20°=0.829; $N_D=1.4601$; Pol.=+25.

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[5] *Ber. d. chem. Ges.* (1903), **36**, 1035.

Experiment 2.—The limonene was distilled from orange peel oil and had the following constants: Specific gravity, $\frac{30^\circ}{4^\circ}=0.8365$; $A\frac{30^\circ}{D}=117.2$; $N\frac{30^\circ}{D}=1.4680$; the hydrochloride, specific gravity, $\frac{30^\circ}{4^\circ}=0.9675$; $N\frac{30^\circ}{D}=1.4770$; $A\frac{30^\circ}{D}=66.5^\circ$. The analysis gave:

	Found (per cent).	Calculated for $C_{10}H_{17}Cl$ (per cent).
Cl	20.26	20.3

Fifty grams of this substance were now put through the Grignard reaction with 9 grams of magnesium and 150 cubic centimeters of dry ether in the apparatus used for experiment 1, the reaction being started with methyl iodide and iodine. There resulted 38 grams of crude oil (calculated 39.8 grams), containing only 0.61 per cent of chlorine, so that 3 per cent of the total hydrochloride used had not been acted upon by the magnesium. This oil was separated into two fractions by careful distillation *in vacuo* with the following results:

No. 1: B. P. 85° to 86° at 40 millimeters, 29.2 grams containing no chlorine.

No. 2: A residue of 7.3 grams containing chlorine.

Number 1 possessed the peculiar, ether-like odor of the dihydroterpene and gave the following constants: Specific gravity, $\frac{30^\circ}{4^\circ}=0.8258$; $N\frac{30^\circ}{D}=1.4580$; $A\frac{30^\circ}{D}=78.2$. The following was the analysis:

0.1468 gram substance gave 0.4674 gram CO_2 and 0.1725 gram H_2O.

	Found (per cent).	Calculated for $C_{10}H_{18}$ (per cent).
C	86.81	86.96
H	13.09	13.04

Twenty-eight grams of the oil $C_{10}H_{18}$ were now diluted with an equal volume of carbon bisulphide, dry hydrogen chloride passed into the mixture to saturation and the whole kept in ice and salt for ten hours. The product was purified in the usual manner and yielded 23 grams of an oil boiling between 110° and 115° at 30 millimeters pressure, 8 grams of residue remaining in the distilling flask. The following were the constants: Specific gravity, $\frac{30^\circ}{4^\circ}=0.931$; $N\frac{30^\circ}{D}=1.4624$; $A\frac{30^\circ}{D}=6.8^\circ$. The analysis gave:

	Found (per cent).	Calculated for $C_{10}H_{19}Cl$ (per cent).
Cl	20.4	20.3

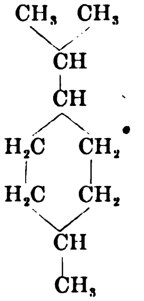
A gram of this oil when treated with sodium ethylate in alcohol, yielded a liquid of very pleasant odor, probably the corresponding ethoxy-derivative. Twenty grams of the chloride so produced were subjected to the Grignard reaction in an atmosphere of hydrogen, 4 grams of magnesium and 60 cubic centimeters of ether being used, the reaction being inaugurated with a little methyl iodide, it proceeded vigorously. There were obtained 14 grams of a chlorine-free oil boiling between 80° and 83° at 40 millimeters pressure. It was redistilled over sodium at ordinary pressure, the final yield being 12 grams of oil of a boiling point 171° to 174°. The product is colorless, with an ethereal odor somewhat resembling that of benzene. Specific gravity, $\frac{30°}{4°}=0.8052$, $N\frac{30°}{D}=1.4459$, $A\frac{30°}{D}=3.7$. The analysis gave the following results:

0.2037 gram substance gave 0.6397 gram CO_2 and 0.2602 gram H_2O.

	Found (per cent).	Calculated for $C_{10}H_{20}$ (per cent).
C	85.64	85.72
H	14.31	14.28

This oil, $C_{10}H_{20}$, dissolves slowly in concentrated sulphuric acid (specific gravity 1.84) without warming or the evolution of sulphur dioxide, giving a slightly reddish solution. The oil is recovered unchanged if the solution is quickly treated with water, more prolonged action of sulphuric acid gives higher boiling products containing sulphur. Concentrated sulphuric acid acts violently on limonene as well as on its reduction product $C_{10}H_{18}$, with marked resin formation and the evolution of sulphur dioxide. Bromine reacts with $C_{10}H_{20}$ by substitution, with the evolution of hydrogen bromide.

Sabatier and Senderson[6] reduced limonene with hydrogen in the presence of nickel sponge at 250° and thus obtained tetrahydro-limonene, the *p*-methylisopropyl-cyclohexane, $C_{10}H_{20}$.



This substance has a boiling point of 169° to 170° and a specific gravity at $\frac{0°}{4°}$ of 0.8132. However, this hydrocarbon was probably not pure, as the authors state, "accompagné d'une petite quantite des produits de deboublemént et para diméthyl et para méthyl éthyl cyclo hexane." Renard[7] obtained from resin oil a hexahydrocymol boiling between 171° and 173° and having a specific gravity of 0.8116 at 17°.

No doubt exists from the above experiments but that I have successively passed from $C_{10}H_{16}$ through $C_{10}H_{18}$ to $C_{10}H_{20}$. An easy method of obtaining tetra and hexahydrobenzene derivatives from terpenes and their derivatives is therefore at hand. It might be questioned that a compound of limonene hydrochloride with magnesium, obtained after the usual manner of the Grignard reaction, is really produced in this instance, as reactions undertaken to produce the classes of synthetic products usually formed by working with similar magnesium derivatives of other halides have not been successful, but the following quantitative experiments remove all doubt of the existence of such a body.

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[6] *Compt. rend. Acad. d. sc.* Par. (1901), **132**, 1256.

[7] *Ann. Chim. Phys.* (1884), (6) **1**, 230.

Experiment 3.—Ten grams of limonene hydrochloride were subjected to the action of magnesium after the usual method of Grignard. The ether, containing the soluble magnesium addition product was then filtered in an atmosphere of dry hydrogen in a similar apparatus to that employed by Freer[8] in his work on sodium acetone. The filtrate was decomposed by means of cracked ice and dilute acid in the usual manner and the magnesium contained in an aliquot portion of the aqueous solution then determined.

	Found (per cent).	Calculated for $C_{10}H_{18}$ MgCl (per cent).
Mg	12.4	12.2

It will be noted that a slight excess of magnesium was found and it seems probable that this is due to the few drops of methyl iodide which must be added to start the reaction. The ethereal solution after adding the ice and acidifying gave 5.7 grams of $C_{10}H_{18}$, with the usual properties. Another fact to be remembered in considering the formation of the magnesium addition product is that there is always a considerable evolution of heat when the latter is decomposed by water, a fact which is difficult to explain if it is assumed that the magnesium has simply acted on limonene hydrochloride as a reducing agent.

It is not advisable at the present time to discuss at greater length which of the possible bodies of the empiric formula $C_{10}H_{18}$ is formed during this reaction. The second reduction product of the formula $C_{10}H_{20}$ always, so far, has possessed a slight optical rotation and this fact renders it probable that the latter has not been obtained entirely pure. However, the above experiments prove beyond any doubt that limonene hydrochloride reacts with magnesium after the normal manner of the Grignard reaction.

It has been shown that alcohol or other compounds containing hydroxyl react with the products of the Grignard reaction according to the following scheme:

$$\text{ROH} + \text{R'MgX} = \text{ROMgX} + \text{R'H}.$$

The reactions with water which have been outlined gave this result. The next step was to study the action of aldehydes upon the product of the interaction of magnesium and limonene hydrochloride in the presence of absolute ether, and benzaldehyde was the first representative of the class selected.

Experiment 4.—Forty grams of limonene hydrochloride, 10 grams of magnesium and 150 cubic centimeters of absolute ether were allowed to react in an atmosphere of dry hydrogen in a strong flask fitted with a mechanical stirrer. After the change was complete, 30 grams of benzaldehyde, dissolved in an equal volume of absolute ether, were added, drop by drop. The reaction was violent, taking place with a considerable evolution of heat, while at the same time a nearly solid, yellowish-colored substance separated. The product was now vigorously stirred for one hour, it was then treated in the usual manner, the ethereal layer being well shaken out with acids and alkalies. The alkaline solution on acidifying gave 2.3 grams of benzoic acid. As the neutral solution, after distilling the ether, did not readily solidify, it was fractioned *in vacuo* with the following result:

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[8] *Ann. Chem.* (*Liebig*), (1894), **278,** 123; **283,** 38.

No. 1: B. P. 85° to 90° at 30 millimeters, 38 grams;
No. 2: B. P. 90° to 130° at 20 millimeters, 3 grams;
No. 3: B. P. 130° to 180° at 20 millimeters, 7 grams;
Tar-like residue, 4 grams.

Decomposition appeared to take place above 130° and excepting the first fraction, there was no indication of a constant boiling substance. No solid bodies could be obtained from numbers 2, 3 and 4, in ice and salt.

Fraction number 1 was dissolved in low boiling petroleum ether and treated with an excess of phenylhydrazine.[9] Thirty-five grams of benzaldehyde phenylhydrazone of a melting point of 154° were thus separated, this quantity corresponds to 18.9 grams of benzaldehyde. The remainder of fraction number 1 consisted for the greater part of $C_{10}H_{18}$.

The higher boiling fractions proved themselves to be an inseparable mixture containing much tar.

As the principal products of the reaction were benzaldehyde and $C_{10}H_{18}$, it was thought possible that the benzaldehyde had not acted upon the Grignard addition product at all, but on the contrary that the yellowish, nearly solid substance was produced by the action of benzaldehyde on magnesium powder in a manner similar to the substances formed by the interaction of sodium and benzaldehyde, as noted by Beckmann and Paul.[10]

To disprove this assumption the action of benzaldehyde on magnesium was studied.

Experiment 5.—Five grams of magnesium powder in absolute ether were rendered active by means of iodine, and a solution of 10 grams benzaldehyde in absolute ether was then added. No action took place even after the whole was heated on a reflux condenser for one hour.

The following experiment demonstrates that when benzaldehyde acts on the product formed by the action of magnesium on limonene hydrochloride it does so in such a manner as *at once to liberate* $C_{10}H_{18}$, or in other words, just as if benzaldehyde were an *alcohol* in this instance.

Experiment 6.—Forty grams of limonene hydrochloride, 10 grams of magnesium and 150 cubic centimeters of absolute ether were taken. The apparatus was in principle like that employed by Freer in his work on sodium acetone. A strong, wide-mouthed flask was fitted with a stopper with five holes, the latter carrying respectively: (1) The inlet for dry hydrogen; (2) the stirrer set in a mercury trap, (3) a dropping funnel, (4) the reflux condenser which was fitted with a glass stopcock sealed into it, and which was protected at its upper end by a tube of soda-lime and (5) a tube running to the bottom of the reaction flask. The latter had sealed onto it a funnel fitted with an asbestos filter and was connected with a filter flask by means of a tube and glass stopcock. The filter flask could be evacuated in the usual manner. After the reaction according to Grignard was complete, 25 grams of benzaldehyde dissolved in absolute ether, were slowly dropped into the flask. The usual, violent reaction with much evolution of heat took place and the yellowish, semisolid substance separated, the whole soon becoming so thick that it was impossible to run the stirrer. After one-half hour, absolute ether to dilute was added in small portions, and by closing the reflux and opening the filter funnel connected with a slight vacuum, the reaction product was separated into two portions, one soluble and the other insoluble in absolute ether; of course, care was taken thoroughly to wash the insoluble part with absolute ether. Both the soluble and insoluble portions were now decomposed by means of ice and acid in the usual manner, the ethereal solutions resulting were separated, dried and the ether distilled.

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[9] It has been shown in this laboratory that benzaldehyde can promptly and satisfactorily be separated from its solution in petroleum ether by phenylhydrazine.

[10] *Ann. Chem. (Liebig)*, (1891), **266**, 6.

Soluble portion: The aqueous solution obtained by decomposing the soluble portion contains *no magnesium*. The neutral oil when treated with an excess of phenylhydrazine in petroleum ether gave 4.1 grams of benzaldehyde phenylhydrazone of a melting point of 153°. The excess of phenylhydrazine was removed by means of dilute sulphuric acid, the petroleum ether distilled and the product fractioned *in vacuo*. Twenty-five grams of an oil boiling between 90° and 93° at 50 millimeters pressure was thus obtained. This fraction contained no chlorine, and after two distillations over sodium at ordinary pressure had the following properties: Boiling point, 175° to 177°, thermometer wholly in the vapor; specific gravity, $\frac{30°}{4°}=0.8250$; $N\frac{30°}{D}=1.4605$; $A\frac{30°}{D}=72.7°$. These properties demonstrate it to be the same compound $C_{10}H_{18}$, produced by the action of water on the body formed by magnesium and limonene hydrochloride. The residual 7 grams in the distilling flask contained a little chlorine and seemed to consist of the diterpene always obtained as a part of the product of the action of magnesium on limonene hydrochloride.

Insoluble portion: Thirty-four grams of benzaldehyde phenylhydrazone of a melting point of 154° after one crystallization from ligroin were obtained by the usual methods from this part.

There remained 6.6 grams of a tar-like oil after removing the excess of phenylhydrazine and from this neither a crystalline solid nor a constant boiling substance could be separated.

Experiments 1, 2, and 3 clearly demonstrate that limonene hydrochloride forms a compound with magnesium of the usual nature of the Grignard addition products, the body being soluble in ether and carrying the theoretical amount of magnesium. Experiment 6 proves that benzaldehyde, acting on this substance, forms a solid body carrying all the magnesium and that this solid when decomposed with water, principally gives benzaldehyde, at the same time the product *soluble in ether and free from magnesium* contains the dihydroterpene $C_{10}H_{18}$, which has been split off from the Grignard body just as if water had reacted with this product. Thus the principal reaction of benzaldehyde on dihydro-limonene magnesium chloride would seem to be:

$$C_{10}H_{17}MgCl + C_6H_5CHO = \underset{\text{(Insoluble in ether.)}}{C_6H_5COMgCl} + \underset{\text{(Soluble in ether.)}}{C_{10}H_{18}}.$$

The evidence for this assumption is made stronger by the following experiments:

Experiment 7.—The following quantities were taken: Limonene hydrochloride, 35 grams; specific gravity, $\frac{30^\circ}{4^\circ} = 0.9770$; $A\frac{30^\circ}{D} = 54.6^\circ$; $N\frac{30^\circ}{D} = 1.4768$; magnesium powder, 6 grams; absolute ether, 100 cubic centimeters. The reaction was carried on throughout as in experiment 6, 23 grams of benzaldehyde free from benzoic acid being used.

Soluble portion: This portion contained no magnesium. The total oil was 20.2 grams, from which, distilled *in vacuo*, the following fractions were obtained:

No. 1: B. P. 75° to 78° at 25 millimeters, 17.2 grams.

No. 2: Residue 2.6 grams.

The usual means of separation gave 4.5 grams of benzaldehyde phenylhydrazone melting at 155° and 156°. The remaining oil, after the removal of the phenylhydrazine, had the following properties: Boiling point, 174° to 176°; specific gravity, $\frac{30^\circ}{4^\circ} = 0.8248$; $N\frac{30^\circ}{D} = 1.4590$; $A\frac{30^\circ}{D} = 37^\circ$; it was therefore $C_{10}H_{18}$.

Summary of the soluble portion.—Benzaldehyde 2.3 grams; $C_{10}H_{18}$, 14.7 grams; residue (diterpenes, etc.), 2.5 grams.

Insoluble portion: The total oil was 31 grams, containing a trace of chlorine. The product, distilled *in vacuo*, at 40 millimeters gave the following fractions:

No. 1: B. P. 80° to 85° at 15 millimeters, 18 grams.

No. 2: B. P. 85° to 215° at 15 millimeters, 7 grams.

No. 3: 3.5 grams of residue.

There were obtained from the above, 22.8 grams of benzaldehyde phenylhydrazone melting at 156° and a liquid with the constants: Boiling point, 175° to 176°; specific gravity, $\frac{30^\circ}{4^\circ} = 0.8254$; $N\frac{30^\circ}{D} = 1.4590$; $A\frac{30^\circ}{D} = 36.8$. There was also isolated 1.1 gram of benzoic acid.

Summary of the insoluble portion.—Benzaldehyde, 12.3 grams; $C_{10}H_{18}$, 7 grams; benzoic acid 1.1 gram, and 8.5 grams of inseparable, high boiling compounds. The presence of the dihydro-limonene is probably due to imperfect washing of the insoluble solid by the ether. This is readily understood when the sticky nature of this body is considered.

Experiment 8.—This experiment was not performed in the elaborate apparatus we had constructed, but instead was carried out in a bromine flask in an atmosphere of dry hydrogen on a water bath.

The following quantities were taken: Limonene hydrochloride, 35 grams; magnesium powder, 6 grams. After the magnesium addition product had been formed, 23 grams of benzaldehyde were added. The usual violent reaction accompanied by the separation of the yellowish solid took place, the whole being finally heated with steam for fourteen hours, during which time the ether rapidly evaporated, as an ordinary reflux condenser does not hold that solvent in this climate. The product was covered with fresh ether, decomposed with ice and dilute acid in the usual manner and the solvent distilled, 55 grams of an oil, which was fractioned *in vacuo*, being obtained.

No. 1: B. P. 70° to 100° at 15 millimeters, 28 grams.
No. 2: B. P. 100° to 150° at 15 millimeters, 12 grams.
No. 3: B. P. 180° to 210° at 15 millimeters (metal bath to 280°), 8 grams.
No. 4: Tarry residue, 4.5 grams.

Number 1 gave 14 grams of benzaldehyde phenylhydrazone and 10 grams of $C_{10}H_{18}$, specific gravity, $\frac{30°}{4°}=0.8304$; $N^{30°}_{D}=1.4640$. Five grams of benzoin melting at 137° after recrystallization from ligroin and 1.2 grams of benzoic acid melting at 121° were obtained from Numbers 2 and 3. The residual 14 grams was a tar-like oil, which regenerated considerable quantities of benzaldehyde on being boiled with dilute acids. It is probably in greater part a mixture of polymers of benzaldehyde.

It is seen from the above that *benzoin*, which should be expected in quantity in the residues of all of these reactions, as it should be formed from a benzaldehyde magnesium compound, is really produced if this compound is heated.

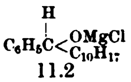
Experiment 9.—There were used 50 grams of limonene hydrochloride and 10 grams magnesium, the reaction (which in this instance unfortunately did not reach completion) being conducted in the apparatus with a filter tube described in Experiment 6. A small amount of the ethereal solution was filtered, decomposed with ice and acid and analyzed, giving 2.6 grams of organic liquid, principally $C_{10}H_{18}$, and 0.307 gram magnesium (calculated Mg=12.2, found=10.3 per cent). The remainder was now also filtered from the unchanged magnesium and from the insoluble portion of the ethereal compound of hydro-limonene magnesium chloride, and the filtrate, which now only contained the *soluble* portion of the addition product, was then treated with 35 grams of benzaldehyde. The usual evolution of heat took place and the yellow solid already described separated, so that the magnesium addition product produced according to the method of Grignard and separated from all other substances by filtration, is in reality the compound taking part in the reaction, any excess of benzaldehyde, or of magnesium powder, which is generally present, not taking part therein. The yellow solid produced from this soluble portion was now again filtered in an atmosphere of dry hydrogen and well washed with absolute ether; it was finally transferred to another flask and placed under absolute ether, it is designated below as the *insoluble portion*. The united etherial solution filtered from this insoluble substance, and the ether used to wash it are termed the *soluble portion*.

The soluble portion: This part was *free from magnesium* and after removing the ether it consisted of an oil which weighed 45 grams in the crude state and which gave the following fractions when distilled *in vacuo:*

No. 1: B. P. 80° to 90° at 20 millimeters, 33 grams.
No. 2: B. P. 90° to 110° at 20 millimeters, 5 grams.
No. 3: A residue of tar, 6 grams.

The above fractions, when treated with the usual reagent gave 35 grams of benzaldehyde phenylhydrazone melting at 155°, representing the excess of benzaldehyde added to the above solution and 14.8 grams of $C_{10}H_{18}$ of a specific gravity at $\frac{30°}{4°}$ of 0.8262 and a refractive index, N^{30}_{D} of 1.4584, the remainder consisted of unchanged limonene hydrochloride and of diterpenes.

The insoluble portion: One and four-tenths grams of the solid remaining under ether was removed, washed with absolute ether, dried rapidly on a porous plate, weighed to a tenth of a gram and thrown into water. The substance proved to be exceedingly unstable in the air, the yellow powder soon becoming very hot, with the separation of a red oil, a behavior similar to that of sodium acetone, while at the same time a very marked odor of benzaldehyde is developed. The powder dissolved rather slowly when thrown into water so that it was necessary to add a little dilute sulphuric acid. The aqueous solution was extracted twice with small quantities of ether, the solvent allowed to evaporate slowly in the air and a crystalline body, which melted at 121° and which proved to be benzoic acid was separated. A very small amount of an oily residue, having the odor of benzaldehyde remained. Magnesium and chlorine determinations were made on aliquot portions of the aqueous solution with the following result:

	Found (per cent).	Calculated (per cent) for	
		$C_6H_5COMgCl$	 $C_6H_5\overset{H}{\overset{\vert}{C}}<^{OMgCl}_{C_{10}H_{17}}$
Cl	20.71	21.5	11.2
Mg	12.8	14.7	7.9

These figures, considering the method used and the difficulty of washing out all free benzaldehyde and the certainty of some oxidation during the transfer, agree very well with those calculated.

The remainder of the solid was heated for three hours on a reflux condenser with 18 grams of benzoyl chloride. The product was then treated with alkali and the neutral part, on distillation, gave 4 grams of benzaldehyde, 1 gram of a solid, mostly benzoic acid[11] and 5 grams of tarry residue. From the alkali 25 grams of benzoic acid were recovered, it is therefore evident that the solid addition product does not react with benzoyl chloride.

Experiment 10.—There were used 10 grams of limonene hydrochloride, 3 grams of magnesium and 40 cubic centimeters of absolute ether. The apparatus was arranged as follows: Flask No. 1 in which the Grignard reaction took place, was fitted with a reflux condenser and a filter tube running to flask No. 2; in this second flask, which also carried a reflux condenser, the filtrate from No. 1 was treated with benzaldehyde, and a second filter tube delivered the filtrate from No. 2 after this reaction, into flask No. 3. All parts were arranged so that they could constantly be kept filled with dry hydrogen. After the Grignard reaction was completed in No. 1, the filtrate which was passed over into No. 2 was treated with benzaldehyde and the solid substance which was formed was well washed with absolute ether, all soluble portions and washings being sucked over into No. 3. On final analysis No. 3 was found to contain no magnesium and only $C_{10}H_{18}$, and the excess of benzaldehyde. The solid in No. 2 was placed under benzene (dried by distilling over sodium wire) and dry oxygen was run into it for eight hours. The reaction is not very marked, this result possibly being due to the fact that the solid forms dense cakes, difficult to penetrate. However, a gradual reddening took place so that the whole, when the current of oxygen was finally shut off had assumed a deep red color. There resulted 1.4 grams of benzoic acid melting at 121°; 0.9 grams benzaldehyde proved by transference into the phenylhydrazone melting at 155° and 1.2 grams of tar. Magnesium and chlorine determinations were made and when calculated on the total substance finally obtained, gave the numbers 11.8 per cent for magnesium and 20.4 per cent for chlorine. Calculated for $C_6H_5COMgCl$, magnesium 14.7 chlorine 21.5 per cent.

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[11] Benzaldehyde oxidizes very rapidly in this hot, moist climate.

Experiment 11.—There were employeed 20 grams of limonene hydrochloride, 100 cubic centimeters of absolute ether and 10 grams of magnesium prepared with iodine according to the method of Von Baeyer.[12] This means of rendering the magnesium active was finally found to be the most satisfactory, as with the metal so prepared the Grignard reaction starts immediately without the aid of any other catalyzer and continues to completion with great vigour. The reaction was carried out in the apparatus used for Experiment 10, 24 grams of benzaldehyde (free from benzoic acid) being added to flask No. 2. The contents of all flasks were worked up in the usual manner.

Flask No. 1 gave 5.2 grams of an oil, principally $C_{10}H_{18}$, representing the portion of $C_{10}H_{17}MgCl$ which was insoluble in the quantity of absolute ether used. The precipitate with benzaldehyde formed in flask No. 2 was very thoroughly washed with absolute ether and immediately worked up; the total oil being 10.6 grams. The following analytical data were obtained:

15.56 grams substance (calculated) gave 1.93 grams magnesium and 3.03 grams chlorine.

	Found (per cent).	Calculated (per cent).
Mg	12.4	14.7
Cl	19.48	21.5

From the 10.6 grams of total oil there were isolated 0.2 gram benzoic acid, 9.1 grams of an oil boiling between 177° and 182°, the latter was converted into 16.5 grams benzaldehyde phenylhydrazone melting at 154°, and 1 gram of a tarry residue remained in the distilling flask.

Flask No. 3 contained only a trace of magnesium and yielded a total of 21 grams of oil boiling between 170° and 183°; from the latter a quantity of benzaldehyde phenyldrazone corresponding to 12.96 grams benzaldehyde was isolated. The remaining liquid which in amount was 10.8 grams, after removing the excess of phenylhydrazine, was the dihydro-terpene $C_{10}H_{18}$. The calculated amount of pure $C_{10}H_{18}$ which would be set free from $C_{10}H_{17}MgCl$ by 9 grams of benzaldehyde (formed by decomposing this magnesium compound in flask No. 2) is 12.4 grams, if the course of the reaction is that which has been assumed in this paper. This agreement is a close one when the inevitable losses in fractionation are considered. In this experiment, therefore, the reaction has been shown to proceed *quantitatively* according to our assumptions.

The combination of magnesium chloride and benzaldehyde which has been so fully discussed, when freshly prepared is exceedingly unstable in the air, oxidizing upon exposure with a marked evolution of heat and with reddening. When left standing under absolute ether it is fairly stable, especially if present in a thick layer, so that if such a thick layer is allowed to stand over night in the open air but little benzoic acid is obtained, the benzaldehyde on acidifying being in greater part recovered as such. Oxidation is rapid if the solid is suspended in ether and a stream of air or of oxygen is passed in, but under these circumstances peroxide formation takes place, and for this reason benzene was chosen instead of ether.

It is entirely premature at the present time to enter into a discussion of the constitution of this addition product. The simplest assumption would assign to it a formula $C_6H_5\overset{\vee}{C}OMgCl$. The structure $$\begin{array}{c}C_6H_5C—O—MgCl\\ \|\\ C_6H_5C—O—MgCl\end{array}$$ does not seem probable, for neither benzoin nor benzil could be found among the substances obtained by decomposing the compound with water, excepting in one experiment (number 8) where heat was used for a long time and where this result was to be expected. However, it is certain that when benzaldehyde acts on the etherial compound of hydrolimonene magnesium chloride, the former reacts as it would do if it contained a hydroxyl group. As in this instance benzaldehyde reacts as if it were an alcohol, it is not surprising to find that acetone does the same, as acetone often assumes the enol form during reactions as, for instance in the production of sodium acetone and during its condensations, many of which are best explainable on the assumption of a compound of the structure $CH_3.COH:CH_2$. It was nevertheless deemed advisable to undertake an experiment with acetone as the reagent.

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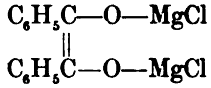
[12] *Ber. d. Chem. Ges.* (1905), **38**, 2759.



Experiment 12.—There were used limonene hydrochloride, 35 grams; magnesium, 10 grams, and absolute ether, 100 cubic centimeters. The Grignard reaction was allowed to take place in a bromine flask, after it was complete, 13 grams of carefully purified and dried acetone were slowly added. A considerable evolution of heat, as is the case with benzaldehyde, was observed and the separation of a solid which at first was red, then yellow and finally white took place. After the reaction has ceased, the product was treated as was the case when benzaldehyde was the reagent. The neutral oils were distilled *in vacuo* and gave the following fractions:

No. 1: B. P. 73° to 80° at 15 millimeters, 20 grams. .
No. 2: B. P. 80° to 110° at 15 millimeters, 7 grams.
No. 3: Residue, 2 grams.

Number 1 was identified as $C_{10}H_{18}$ as it had the following constants: Boiling point, 174° to 176°; specific gravity, $\frac{30°}{4°}=0.8280$; $N^{30°}_{D}=1.4630$.

Number 2 contained a considerable amount of chlorine and the oil was doubtless a mixture of unchanged limonene hydrochloride and diterpenes. The method of Denigès [13] showed 12.6 grams of acetone to be present in the aqueous solution.

This result is parallel with the one obtained with benzaldehyde and therefore, in this reaction, also, acetone assumes the rôle of propen–1–ol–2.

These experiences with limonene hydrochloride were of sufficient interest to warrant a study of the action of benzaldehyde on other magnesium organic halides, for it might be true that in each instance a certain proportion of the reduced hydrocarbon might be produced, owing to the small percentage of the enol form present in the aldehyde: with this end in view a study of the reaction between benzyl magnesium chloride and benzaldehyde was undertaken. Thus Grignard[14] states that benzyl magnesium halides do not react in the normal manner with aldehydes, the principal product of the reaction being dibenzyl, and Hell[15] and his students, depending upon the conditions, obtained both the carbinol and stilben in this reaction.

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[13] *Compt. rend. d. Acad. sci. Par.* (1898), **127**, 963; *Ann. Chim. Phys.* (1899), (6), **18**, 400. *Bull Soc. Chim.* (1899), (3) **21**, 241.

Several experiments under varying conditions were performed and phenyl-benzyl carbinol was always obtained in large quantities, but in no case could toluol be detected. Phenyl-benzyl carbinol is readily obtained in the pure state by distillation of the reaction product *in vacuo.* It boils from 167° to 170° at 10 millimeters pressure and immediately solidifies in the receiver, the room temperature being 30° to 33°. Hell speaks of the difficulty he experienced in obtaining the carbinol in a solid form when working in the summer. Crystallized twice from ligroin (in which solvent when it is boiling it is quite soluble, whereas it is almost insoluble in the cold), it melts at 67° to 68°. The melting points given for phenyl-benzyl carbinol in the older literature are too low.[16]

With concentrated sulphuric acid it gives a white tar, just as benzhydrol gives a red tar with the same reagent.

As the method of preparing benzhydrol[17] in quantity has in the past been tedious to apply, and as the Grignard reaction was under consideration, it was decided to ascertain if it might be available for this purpose. Using chlor- or brom-benzol, magnesium and ether, and treating the reaction product with benzaldehyde, the results leave nothing to be desired as to yield, ease of manipulation and time consumed, so that this method will undoubtedly replace the longer ones formerly used in preparing this compound.

SUMMARY.

Limonene hydrochloride reacts with magnesium to form a hydrolimonene magnesium chloride, soluble in absolute ether, the union taking place normally according to the type of reactions discovered by Grignard. This addition product when decomposed by water gives a dihydro-terpene $C_{10}H_{18}$.

A method is developed by means of the Grignard reaction of passing from terpenes and their derivatives to di- and tetrahydro-terpenes and their derivatives, and thus a very simple and accessible means of preparing tetra- and hexahydro-benzene derivatives is at hand.

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[14] *Ann. de l'Université de Lyon* (1901), N. S. **6**, 1–116; *Chem. Centrbl.* (1901), **II**, 623.

[15] *Ber. d. Chem. Ges.* (1904), **37**, 453, 225, 1429.

[16] Limpricht and Schwanert: *Ann. chem.* (*Liebig*), (1870), **155**, 62. Goldberg: *Ibid.* (1874), **174**, 332. Knovenagel and Arndts: *Ber. d. chem. Ges.* (1902), **35**, 1987. Sudborough: *J. chem. Soc.* London (1895), **67**, 605. Beilstein II, 1079 gives M. P. 42° probably a misprint for 62°. The error has been copied into Richter's Lexikon der Kohlenstoffverbindungen.

[17] Nef: *Ann. Chem.* (*Liebig*), (1897), **298**, 202. Bacon: *Am. Chem. Jour.* (1905), **33**, 68.

It has been proved by quantitative experiments that with hydro-limonene magnesium chloride, benzaldehyde acts as if it contained a hydroxyl group.

The solid product of the action of benzaldehyde upon hydro-limonene magnesium chloride gives analytical data which point to the formula $C_6H_5COMgCl$. When decomposed with dilute acids this compound regenerates nearly quantitative amounts of benzaldehyde, and only when it had been heated for a long time are products like benzoin obtained, which would indicate a double molecule.

The compound $C_6H_5COMgCl$ is, when freshly prepared, very unstable in the air, its behavior being much like that of sodium acetone. Acetone, like benzaldehyde, also reacts as if it contained a hydroxyl group.

No analogous reaction was obtained from benzyl magnesium chloride and benzaldehyde.

Work with the Grignard reaction in the field of the terpenes will be continued.

PHILIPPINE TERPENES AND ESSENTIAL OILS, II. YLANG-YLANG OIL.

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INTRODUCTION.

The ylang-ylang oil industry is the most important and in fact at present practically the only perfume-oil industry in the Philippines. Like Manila hemp, the ylang-ylang (flower of flowers) is peculiarly a product of the Philippines, as the oil distilled in other tropical countries, prepared from the same tree, is not ranked in the same class, as regards quality, with the product of this Archipelago, but is sold as "cananga" oil. Ylang-ylang oil is obtained by steam distillation from the flowers of *Canangium odoratum* Baill. (*Cananga odorata* Hook. f. et Th.). Some idea of the magnitude of the industry may be obtained from the following extracts from the reports of the Philippine custom-house showing the amounts of this oil exported during the fiscal years named:

TABLE I.—*Export of ylang-ylang oil from 1900 to 1907, inclusive.*[1]

Year.	Kilos.	Year.	Kilos.
1900	19,647	1904	10,917
1901	7,515	1905	13,395
1902	11,847	1906	27,909
1903	17,826	1907	27,036

Figures available for the Spanish régime.

Year.	Kilos.	Year.	Kilos.
1885	1,703	1890	1,612
1886	1,487	1892	11,095
1887	1,181	1893	2,284
1888	.899	1894	1,621
1889	1,080		

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[1] These figures represent gross weights of the packages and hence do not represent the actual amounts of oil exported, on which no figures are available. To obtain the actual weights of ylang-ylang oil exported the figures given should probably be divided by ten.

It is thus evident that the industry is rapidly increasing in magnitude, as perfumers are now using this fine oil in an increasing number of products. As the industry is peculiarly one belonging to the Philippines, this laboratory has undertaken studies on the oil and the best means of its distillation, with the view of improving the methods of manufacture and of the quality of the oil. The results thus far obtained are recorded in this paper.

GENERAL TRADE CONDITIONS.

The general trade conditions in the ylang-ylang oil industry are not particularly promising for a person with limited capital who desires to engage in this business. Necessarily, the price of the oil depends upon its quality, but the establishment of a brand is of very great importance. Oils of long established brand command a higher price than unbranded ones, or than oils of newer brands, although the latter may be fully as good in every respect. Many European houses buy only through Manila firms with whom they have contracts and will not purchase oil from others, no matter what the quality may be. Nevertheless, there is a large open market, especially with French houses, for *first-class* oils, and oils of the very best quality can always be sold. The price naturally varies according to the supply and demand, but the very best oils may be counted upon to bring about 200 pesos, Philippine currency, per kilo [2] and those of established brands bring even higher prices. The conditions in regard to second-grade oils are not by any means as favorable.[3] The demand for these oils is small, probably because of competition with cananga oil and with artificial ylang-ylang oil. Most of the Manila distillers manufacture both first and second grade oils and because of their trade connections they are usually able to dispose of stocks of the latter. The distillers in the provinces who, because of ignorance of the best methods of distillation and of poor apparatus, usually manufacture only second-grade oils, often find great difficulty in selling their product. These provincial distillers are generally anxious to realize quickly on their stocks, which they sell to the Manila firms for the best price offered. The price paid in Manila for such provincial oils is about 30 to 70 pesos, Philippine currency, per kilo. There is often so little demand for second quality oils that they can not be sold in Manila for any price, and the European market for this grade is frequently so inactive that distillers may have such oils on their hands for as long a period as two years before disposing of them.

[2] One peso, Philippine currency, is equal to one-half a dollar, United States currency.

[3] Interesting in connection with the present prices of ylang-ylang oil is Gals article on this substance (*Compt. rend. acad. d. Sc. Par.* (1873), **76**, 1482, in which it is stated that the price of the oil at that time was 2,500 francs the kilo. He calls the oil essence of alan-gilan or hilan-hilan from *Unona odoratissima*, a synonym of *Canangium odoratum*.

In general, the distillers do not own their own groves of ylang-ylang trees, and the market for the flowers in the region around Manila is in a very unsatisfactory condition for the distiller. The large number of distilleries in Manila causes keen competition for the flowers; as a result the quality sold is very poor and the price is high. One of the largest firms in this business states that the flowers are of a much poorer grade during the past few years than they were several years ago.

The flowers are usually picked in the night and are collected in small lots early in the morning by native brokers who deliver them at the distilleries. The natives make a practice of wetting the flowers with as much water as they will absorb and there will often be leaves, twigs, and other substances mixed in with them to add weight. The distillers hardly dare refuse such materials, although the quality is poor, for fear their supply may be altogether cut off. I should estimate that over three-fourths of the flowers brought to the distillers in Manila are unripe and green, although the ripe, yellow product gives a larger yield of much superior oil. The price of flowers in Manila varies from 20 to 40 centavos, Philippine currency, per kilo, the average probably being as high as 30 centavos.[4] Many people in the Islands have an idea that the ylang-ylang distillers make a tremendous profit. From my observation, of the business I can not believe this opinion to be well founded. It probably requires on an average 350 kilos of flowers to produce 1 kilo of first-class oil and this amount will also probably give an additional three-quarters of a kilo of second-class oil. Thus the flowers for 1 kilo of first-class oil will probably cost 115 pesos, Philippine currency, and after the cost of steam and water used, of skilled supervision, interest and depreciation of the plant are added only a legitimate profit is left. The grower seems to be the one who makes the large profits in this industry, as I have heard of trees being sublet by the year for 2 pesos per month, the renter expecting to make a profit from the flowers which he can pick from the tree. This would mean a production of at least 80 kilos of flowers from one tree during a year. We have no figures, nor have we been able to obtain any reliable data on the point of the yield of flowers from one tree, but there is no doubt but that large trees bear very luxuriantly. In Manila, the best flowers are usually obtained in May and June, but the season just passed

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[4] In Piesse's Art of Perfumery, London, (1891), 134, is found an interesting error in the statement that ylang-ylang flowers are adulterated with flowers of champaca (*Michelia champaca* Linn.) to cheapen the quality of the oil. As a matter of fact champaca flowers sell in Manila for as high as 1 peso, Philippine currency, per kilo with a good demand as compared to ylang-ylang flowers at about 30 centavos, Philippine currency, per kilo, and oil of champaca is much more expensive than oil of ylang-ylang. An idea prevails in Manila that the distillers make much money by sorting out the champaca flowers from the ylang-ylang flowers, as in some localities both classes of trees grow in the same grove. This idea is also erroneous.

(1907) was late, so that distillation was not begun on any large scale until August (1907) and it then extended into February (1908).

Large numbers of ylang-ylang trees grow in many of the provinces; in the Camarines, Mindoro, and Albay there are stills, and in Bohol there are many trees, but as yet no stills. The trees are also probably found in quantities in many of the other provinces, where oil is not yet distilled.

The impression is very general in Manila that the provincial flowers are inferior and will not make good oil. This opinion is no doubt largely due to the lower quality of provincial oils caused by poor distillation. There is every reason to believe that the flowers are just as good in the provinces as in the region around Manila, especially in those regions where the trees are cultivated and raised on a large scale. Some firms in Manila distill oil in the provinces, and the prices which they obtain are just as high as those derived from their Manila product. Moreover, the provincial distiller has two very decided advantages over his Manila competitors in that the price which he pays for flowers is lower (12 to 20 centavos, Philippine currency, per kilo), and in that he can refuse to accept poor flowers, as the competition is not so keen. The next advance for the industry would seem to be the installation of first-class apparatus and the introduction of correct distillation methods in the provinces.

METHODS OF DISTILLATION.

Much mystery surrounds the distillation of the oil of ylang-ylang in Manila. The manufacturers are supposed to have valuable trade secrets, so that no one is allowed to visit the distilleries of many of them. However, I have been inside of some of the Manila distilleries where no such restrictions exist and have also distilled the first quality of ylang-ylang oil in this laboratory. I do not wish to violate any confidence imposed in me by the manufacturers who have allowed me to visit their plants and have told me of their methods of distillation, but I do not believe there are any trade secrets; by this I do not mean to imply that any one can distill first quality ylang-ylang oil, but with the proper apparatus an operator who thoroughly understands the distillation of essential oils in general will soon find out the special small points in the distillation of ylang-ylang oil. The important points where many err, and this is especially true of the provincial distillers, is in the wrong choice of fractions, in burning the flowers and in obtaining too much resin in the oil. The oil must be distilled slowly, with *clean steam*, the flowers being so placed in the stills as to avoid their being cut into channels by the steam. The quantity of the oil taken is only a fraction of the total amount in the flowers. Disregard of this factor is one of the most grievous errors of the provincial distillers, for, on the contrary, they are usually too anxious to obtain a large yield of oil, and therefore they will often distill 1 kilo from 150 to 200 kilos of flowers. The quantity of the latter to be taken to produce 1 kilo of oil naturally varies with their quality, but in general the amount should be 300 to 500 kilos, probably averaging about 400. After the first quality oil has been distilled, then a varying quantity of the second grade, up to a volume equal to that of the first, may be obtained from the same lot of flowers; after this operation the still and condensers must be thoroughly cleaned and steamed out to prevent contamination of the next distillation of first-quality oil with the remains of the second quality adhering to the apparatus. The distiller usually judges of the time to change the receptacle from that used for first quality to that employed for the second, by taking note of the odor of the distillate. The oil is received in some type of Florence flask, usually two or more of these are connected in series and the condensed water is used in future distillations. The whole apparatus is best lined with block tin, although some distillers have found nickel to be more satisfactory. The oil, after separating from the water, is clarified and as it is sensitive to light and air, it should be placed into dark colored bottles as soon as possible; these should be filled to the neck, well stoppered and then paraffined to keep out all air. In the ideal apparatus the receivers should be so constructed that very little light and air has access to the oil. The possibilities of vacuum distillation with steam to obtain as large a yield as possible of the fragant lower boiling esters and alcohols and as little as possible of resins and sesquiterpenes, has suggested itself. Some experiments along these lines were undertaken, but the apparatus available was not satisfactory for the purpose owing to losses in the condensers. The maceration of the flowers to allow the oil to escape more easily also suggests itself as a possible improvement in distillation methods. Experiments along these lines will be undertaken at some future time when a new still, adapted to the purpose, has been purchased.

THE ANALYSIS OF YLANG-YLANG OIL.

Ylang-ylang oil does not owe its fragrance to any one substance, but contains a great number of odoriferous compounds, hence it is not possible to value it by certain analytical determinations as is the case with many essential oils. At the present time ylang-ylang oil is largely bought and sold on the judgment of the dealers, the determining factor being the odor, and much prejudice as well as uncertainty of valuation exists. It is highly desirable to have other means of determining the value of the oil. This would be especially advantageous for those Manila houses who purchase oils other than those of their own manufacture, as experience has shown to these firms that the judgment of the purchaser in Manila does not always agree with that of the one in Europe. It is obvious that it is not possible in the present state of our knowledge of ylang-ylang oil to judge of its quality from the analysis alone, but I believe the following results will show that the ordinary analytical constants are of very great assistance, as only the records of isolated constants obtained on oils largely of unknown origin are available in the literature. Owing to this lack I have determined the simple constants on a number of oils of known origin. Most of the latter were from one distillery, the process of distillation being watched and the samples collected by myself. In this manner I was able to obtain a few analytical constants on oils known to be of first or second grade; the results recorded present many regularities and are so promising that it is hoped, as more material becomes available, to discover other constants, so that in time the purchase and sale of ylang-ylang oil may be placed on an exact analytical basis. In this first series the values determined were: Specific gravity at $\frac{30^\circ}{4^\circ}$ (pyknometer); optical rotation at 30°; refractive index, $N\frac{30}{D}$; and ester number, the latter by the usual method, using 1 gram of oil. The results are tabulated as follows:

TABLE II.—*Tabulation of the constants of first-grade ylang-ylang oils.*

No.	Sp. gr. $\frac{30^\circ}{4^\circ}$	$A\frac{30^\circ}{D}$	$N\frac{30^\circ}{D}$	Ester number.	Origin and remarks.
1	0.941	−43.6	--------	129.7	My distillation, Apr., 1907. First 0.45 per cent from 10 kilos of good flowers.
2	0.920	−35.5	1.4846	108	B.'s distillate of Aug. 17, 1907.
3	0.911	−39.3	1.4840	95	First half of first-quality oil distilled Aug. 17, 1907.
4	0.921	−35.1	1.4821	109	B.'s distillate of Aug. 20, 1907.
5	0.939	−34.2	1.4880	131	B.'s distillate of Aug. 22, 1907.
6	0.920	−38.9	1.4838	98	B.'s distillate of Aug. 23, 1907.
7	0.925	−45.2	1.4900	110	B.'s distillate of Aug. 24, 1907. Typhoons and poor flowers.
8	0.919	−45.9	1.4864	100	B.'s distillate of Aug. 27, 1907. Rains and typhoons.
9	0.912	−48.2	1.4852	90	B.'s distillate of Aug. 29, 1907. Flowers very poor because of continued typhoons.
10	0.922	−26.0	1.4794	117	First quality oil rectified *in vacuo*. B.'s distillate 90 per cent yield.
11	0.915	45.6	1.4843	96	B.'s distillate of Aug. 31, 1907. Flowers so poor because of continued typhoons that 500 kilos were used for 1 kilo of oil.
12	0.913	−38.3	1.4808	95	B.'s distillate of Sept. 5, 1907. Flowers good as a result of three days' sunshine and hence a large yield of oil.
13	0.924	−49.7	1.4898	104	B.'s distillate of Sept. 7, 1907.
14	0.927	−44.4	1.4883	112	B.'s mixed distillate.
15	0.916	−36.9	1.4811	100	B.'s distillate of Sept. 10, 1907.
16	0.915	−33.2	1.4747	102	Distillate 55 grams obtained by redistilling 100 kilos of ylang-ylang condensation water.
17	0.917	39.8	1.4785	96	B.'s distillate of Sept. 12, 1907.
18	0.922	45.9	1.4890	104	B.'s distillate of Sept. 3, 1907.
19	0.921	−40.7	1.4825	108	B.'s mixed distillate.
20	0.914	−37.9	1.4895	101	First-quality oil from Mindoro.
21	0.949	−36.1	1.4940	138	Distilled *in vacuo* with steam from selected flowers.
22	0.827	−42.2	1.4912	126	B.'s distillate of Feb. 1, 1908, from very good flowers.
23	0.958	−27.0	1.4910	169	0.4 per cent yield from selected flowers with very careful distillation. A very fine oil.

Table III.—*Tabulation of the constants of second-grade ylang-ylang oils.*

No.	Sp. gr. $\frac{30^\circ}{4^\circ}$	$A\frac{30^\circ}{D}$	$N\frac{30^\circ}{D}$	Ester number.	Origin and remarks.
1	0.929	—69.2	----------	84.6	Corresponds to No. 1, above. Second 0.42 per cent from same distillation as No. 1.
2	0.910	-27.7	----------	89	First half by distillation *in vacuo* from a provincial oil.
3	0.015	—56.3	----------	42	Second half by distillation *in vacuo* of the same provincial oil.
4	0.910	—27.4	----------	64.1	Provincial oil from Nueva Caceres. Distillate of Mar., 1907.
5	0.912	-51.5	----------	83	My distillation; poor flowers; 0.45 per cent yield.
6	0.921	—55.7	----------	75	My distillation; poor flowers; 0.52 per cent yield.
7	0.940	—38.8	----------	80	My distillation; poor flowers; 0.61 per cent yield.
8	0.918	—42.7	1.4950	84	Provincial oil.
9	0.918	—37.2	1.4954	77.1	Do.
10	0.942	—31.3	1.4978	87	Corresponds to No. 3, Table II. B.'s second-quality oil of Aug. 17, 1907.
11	0.913	—86.0	1.5000	72	Corresponds to No. 4, Table II. B.'s second-quality oil of Aug. 20, 1907.
12	0.917	—66.7	1.5032	70	My distillation of second-quality oil from flowers from which the first quality had been previously distilled. Yield, 0.7 per cent.
13	0.919	—61.4	1.4977	86	Second-quality oil corresponding to No. 5, Table II.
14	0.918	—66.4	1.4986	83	Second-quality oil corresponding to No. 6, Table II.
15	0.903	—81.3	1.4981	59	Second-quality oil corresponding to No. 7, Table II.
16	0.928	—30.2	1.4927	64	Provincial oil.
17	0.918	—73.5	1.4979	80.8	Second-quality oil corresponding to No. 8, Table II.
18	0.906	—76.0	1.4991	67	Second-quality oil corresponding to No. 9, Table II.
19	0.926	—75.0	1.5054	80	Second-quality oil corresponding to No. 11, Table II.
20	0.901	—44.4	1.4935	54	Provincial oil.
21	0.896	—46.8	1.4838	72	Provincial oil No. 20 rectified *in vacuo;* 0.65 per cent yield.
22	0.897	—29.8	1.4758	69	Provincial oil No. 20 rectified *in vacuo;* 0.50 per cent yield.
23	0.914	—84.7	1.5001	73	Second-quality oil corresponding to No. 12, Table II.
24	0.913	—66.8	1.4926	86	Second-grade "Sartorius" brand.[a]
25	0.910	—69.0	1.4972	69	Second-quality oil corresponding to No. 13, Table II.
26	0.904	—87.0	1.4980	68	Second-quality oil corresponding to No. 15, Table II.
27	0.922	—35.8	1.4962	77	Provincial oil.
28	0.926	—51.6	1.5002	89	Do.
29	0.913	—34.3	1.4980	86	Do.
30	0.915	—43.3	1.4962	81	Iriga oil. Approaches first-grade oil in quality.
31	0.921	—36.2	1.5002	94	Oil from Guinobatan, Albay. Approaches first-grade oil in quality.
32	0.914	—55.4	1.5008	82	Second-quality oil from same locality. Same distillation.
33	0.920	—42.6	1.4916	85	Good second-quality oil from B's plant.
34	0.912	—45.6	1.4928	90	Oil from Nueva Caceres. Approaches first-grade in quality.
35	0.908	—30.1	1.5082	53	Oil from Mount Isarog, Ambos Camarines. A very poor oil.
36	0.912	—32.1	1.4942	86	Oil from Albay. Very close to first-grade oil.

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[a] The manufacturers of the "Sartorius", one of the best brands of ylang-ylang oil, have refused to sell us any of their first-quality oil, and the analysis of number 24 was made from the second quality of the oil, sold in Manila as "essence of ylang-ylang de Pablo Sartorius." We expect to be able to obtain the first-grade oil from European sources, and hope to include this standard brand in our future work.

DISCUSSION OF ANALYTICAL RESULTS.

Several regularities will at once be noted. The ester number of first-grade oils is usually 100 or more, whereas that of second grade but rarely rises above 80; the refractive index of the former class is usually low, being but rarely over $N\frac{30^\circ}{D}=1.4900$, whereas that of the latter approaches 1.5000. This difference is due to the larger content of sesquiterpenes and resins in second-grade oils, cadinene having a refractive index $N\frac{30^\circ}{D}=1.5060$. The optical rotation of first-grade oils is much lower than that of the second grade, it being but rarely over —45° and usually varying from —32° to —45°, that of the second grade being around —60° and over. This difference is also caused by the high content of the latter in sesquiterpenes. A few provincial oils have a low optical rotation together with a low ester number, and such oils are in general very poor, they are also apt to have a very low specific gravity.[5] The results all go to show that an oil with a low refractive index, low optical rotations, and high ester number is almost certain to be good, while high refractive index, high optical rotation, and low ester number indicate a second-grade oil.

No especial regularities have been noted in the specific gravities of the various oils, save that if an oil has a high specific gravity and high ester content (ester number above 110) it may follow that it may also have a higher refractive index, and oils with all these constants are very superior. (See Table II, number 23.)

Manila buyers of provincial oils are often anxious to ascertain the quantity of flowers used by the distiller in obtaining the oil offered, so that they may judge as to its quality. A number of experiments were made on the distillation of ylang-ylang oil *in vacuo* to obtain data on this point and to ascertain whether it might be possible to rectify a lower grade of oil by such a procedure.

One hundred cubic centimeters of first-quality oil were placed in a 200 cubic centimeter, high-necked flask, the distance from the surface of the oil to the exit tube being 16.5 centimeters; a slow, regular distillation was made from a metal bath the temperature of which was kept 15° to 20° hotter than that of the distilling vapor; the total time consumed in the distillation being one hour and twenty-five minutes.

The original oil gave the following constants: Specific gravity, $\frac{30^\circ}{4^\circ}=0.927$; $A\frac{30^\circ}{D}=-44.4$; $N\frac{30^\circ}{D}=-1.4883$; ester number=117.8.

Fraction number 1.—Fifty-two cubic centimeters at 13 millimeters pressure, passing over between 73° and 100°, temperature of metal bath up to 120°.

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[5] Cf. Table III, numbers 4, 9, 16, 21, 27, 35, all of which numbers were known to represent very poor oils.

A perfectly colorless oil of very good odor but lacking the fine, sweetish, soft flavor of the original.

Specific gravity, $\frac{30^\circ}{4^\circ}=0.921$; A $\frac{30^\circ}{D}=21.1$; N $\frac{30^\circ}{D}=1.4778$; ester number=120.

***Fraction number 2.*—Twenty-five cubic centimeters at 13 millimeters pressure, boiling between 100° and 120°, metal bath up to 135°.**

A water-white oil having a burnt odor.

Specific gravity, $\frac{30^\circ}{4^\circ}=0.916$; N $\frac{30^\circ}{D}=1.4890$; A $\frac{30^\circ}{D}=-68.2$; ester number=75.

***Fraction number 3.*—Fifteen cubic centimeters at 10 millimeters pressure, passing over between 120° and 142°, metal bath up to 155°.**

Specific gravity, $\frac{30^\circ}{D}=0.910$; A $\frac{30^\circ}{D}=-97.8$; N $\frac{30^\circ}{D}=1.5031$; ester number= 109.

The residue in the distilling flask was 6 cubic centimeters, N 30=1.5435. A dark brown resin, of rather agreeable odor.

Fractions 1, 2, and 3, united, gave 92 per cent of the original oil. This oil was perfectly colorless, but the odor was burnt and not nearly as fine as that of the original oil.

The constants were: Specific gravity, $\frac{30^\circ}{4^\circ}=0.918$; A $\frac{30^\circ}{D}=-46.5$; N $\frac{30^\circ}{D}=$ 1.4841; ester number=117.1.

The greater part of the burnt odor was removed by running air through this oil for some time, but this process did not restore the mild, sweetish odor of the original oil. When, during the process of distillation the distillers slightly burn the flowers which they use, the resulting oil is allowed to stand in contact with the air for a day or two, the result being the loss of its burnt odor. I have noted in respect to oils distilled *in vacuo* that those samples distilled in a hydrogen atmosphere always have more of a burnt, or flat odor than have the ones fractioned with the ordinary air capillary. My experience seems to be that the rectification of oils *in vacuo* is not an entire success, as the distillates, although apparently of the same composition as the oil from which they are distilled, seem to lack in perfuming power; this is especially true of the lasting qualities of the odor. These results suggest that the highest boiling parts of the ylang-ylang oil and even the resins, are very probably important constituents of the whole, possibly they help to fix the more volatile, odoriferous portions. I have always been impressed by the peculiarly lasting fragrance of the resinous residues of the distillation of ylang-ylang oils fractioned *in vacuo*.

The distillation of many ylang-ylang-oils *in vacuo* has shown that over 50 per cent of the first quality oil will pass over below 100° at 10 millimeters pressure, and when I have tested poorer oils in this respect I have found the amount of substance volatile below 100° at 10 millimeters which passed over to be proportional to the quantity of flowers used in preparing the oil. Thus one oil distilled from flowers at the yield of 1 kilo for 206 kilos of flowers showed 27 per cent of volatile constituents under the conditions named, whereas another prepared in the proportion of 1 kilo to 150 kilos of flowers gave 19 per cent.

It follows from this that the distillation test is also of value both in determining the quality of an oil and the proportion of flowers used in preparing it. The only manner in which poor provincial oils may be improved is by redistillation with steam, and this procedure results in large losses. Fractioning with steam *in vacuo* also seems quite promising, although the process is very slow. Oils thus obtained are quite colorless, and by taking suitable fractions a very fair oil may thus be prepared from a product which before treatment was almost unsalable.

The following table illustrates the manner in which the very significant constants of refractive index and ester number vary in the different fractions. The numbers represent the successive fractions obtained at L.'s distillery on the dates given:

TABLE IV.—*Successive fractions of ylang-ylang oil.*

No.	April 9, 1907.		April 11, 1907.			September 21, 1907.	
	$N\frac{30°}{D}$	Ester number.	$N\frac{30°}{D}$	Ester number.	Specific gravity.	$N\frac{30°}{D}$	Ester number.
1	1.4878	163	1.4777	102	0.927	1.4888	165
2	1.4908	149	1.4825	185	0.930	1.4903	167
3	1.1970	105	1.4906	119	0.929	1.4945	145
4	1.512	88	1.4978	91	0.931	1.5003	105
5	1.5050	65	1.4994	83	0.924	1.5035	86
6	1.5057	68	1.5040	55	0.929	1.5029	73
7	1.5041	58	1.5068	60	0.933	1.5030	61
8			1.5083	64	0.940	1.5034	57
9						1.5023	54
10						1.5000	49

A double refined oil (twice distilled) from the same firm gave as follows for the first and second fractions:

1. $N\frac{30°}{D}=1.4921$; specific gravity=0.922; ester number=105.
2. $N\frac{30°}{D}=1.4978$; specific gravity=0.934; ester number=92.

THE ADULTERATION OF YLANG-YLANG OIL.

I do not believe that adulteration of ylang-ylang oil is very general in the Philippines. The common adulterants are said to be alcohol, turpentine, coconut or other fixed oils, and kerosene. When turpentine is used as an adulterant, it is sprinkled over the flowers and then subjected to distillation with the rest and when small quantities are thus used its detection is exceedingly difficult, as pinene has been reported as a normal, lesser constituent of true ylang-ylang oil. The presence of terpenes in ylang-ylang oil probably depends upon the fact that unripe flowers in which terpenes are apt to occur are mixed with those used for distilling. I could not find pinene or other terpenes in 100 cubic centimeter samples of oils made from fairly good flowers, but the distillation of very unripe flowers gives an oil which has an odor differing entirely from that of ylang-ylang; on the other hand it resembles that of a mixture of turpentine and bananas, and doubtless it contains quantities of terpenes and of benzyl or amyl (?) acetate.

I have examined a sample of turpentine which was said to be prepared for the use of ylang-ylang distillers; it proved to be a very thoroughly refined, dextro-rotary product, flavored with a trace of essence of peppermint. If turpentine is present in an ylang-ylang oil in any quantity it gives to the latter a sharp, harsh odor, it lowers the specific gravity, optical rotation and refractive index, and it may be detected in the first fraction upon distilling the ylang-ylang oil *in vacuo*. If, upon fractioning a 100 cubic centimeter sample at 10 millimeters pressure, more than 1 cubic centimeter passes over below 65°, turpentine or some other low-boiling adulterant may be at once suspected. The odor of this fraction will often give some clue as to the adulterant which has been used and if it is suspected that this is turpentine, pinene may be tested for in the usual manner. The presence of pinene is best proved by its conversion into the bisnitroso-chloride, which with benzylamine gives the corresponding nitrol benzylamine melting at 123°.

Alcohol is detected in ylang-ylang oil by shaking the sample thoroughly three times with a small amount of water, the latter being thoroughly separated from the oil by centrifugating. The iodoform reaction is then used with the aqueous solution, sodium carbonate and iodine dissolved in potassium iodide being added. I have satisfied myself that pure ylang-ylang oil gives no reaction with these reagents and that 1 per cent of alcohol can be detected in a 20 cubic centimeter sample by this method. Pure ylang-ylang oil will sometimes give a faint reaction. This is no doubt owing to the alcohol which is used in washing the funnels and flasks in the distillery.

Coconut or other fatty oils are detected by the well-known method of placing a drop of the oil on bibulous paper, and this course is satisfactory if the adulterant is present in any quantity. The solubility in 90 per cent alcohol has also been proposed as a test, as fatty oils are soluble with difficulty in alcohol of this strength. I have found that 3 per cent of coconut oil added to an ylang-ylang oil of the first quality could be at once detected by the opalescence produced by treating the mixture with two volumes of 90 per cent alcohol. However, the test, if used indiscriminately is liable to lead to unreliable results, because a pure, second-grade ylang-ylang oil gives a marked opalescence with alcohol of the same strength; this is due to the fact that sesquiterpenes preponderate in this quality and the latter are insoluble in 90 per cent alcohol. The difference becomes more marked on using 75 per cent alcohol, as the first quality of ylang-ylang oil dissolves in this strength with only a faint opalescence, while second quality separates in large globules; so that this distinction offers an easy method of roughly judging the quality of the oil.

Another method of value is to prepare a 1 per cent solution of the oil in alcohol and compare the odor with a similar one of an oil of known quality, as judgment is much more certain as to the perfuming power when dilute solutions instead of the pure oils are used. One cubic centimeter of each solution can then be poured on separate pieces of bibulous paper, the odor being compared at the end of twelve, twenty-four, or even a longer number of hours; this test gives some idea in regard to the permanence of the odor.

Pure ylang-ylang oil obtained by distillation *in vacuo* leaves a residue of about 5 per cent and of course if fixed oils are present, this will be larger. Moreover, the residue from pure ylang-ylang oil has a refractive index $N\frac{30^\circ}{D}$ of about 1.5400, whereas a product containing 5 per cent of added coconut oil had an index of $N\frac{30^\circ}{D}=1.5000$. Fatty acids can be detected in this residue left on distillation by heating it with fused potassium bisulphate, for if fatty oils are present the odor of fatty acids as well as a marked one of akroleïn is observed. The odor of the fatty acids gives the best sign of their presence in the residue, because pure ylang-ylang oil upon being treated in this way gives a rather sharp odor, which, however, might be mistaken for that of akroleïn. If coconut oil has been added to a first-grade ylang-ylang oil to the amount of 5 per cent it can be detected by the odor alone, if the person making the test is familiar with the oil. Petroleum or mineral oil can be detected in ylang-ylang by destroying everything but these adulterants with concentrated sulphuric acid and then distilling the remainder.

The use of any adulteration is more emphatically the height of commercial folly for ylang-ylang than it is for any other essential oil, for only the product of the highest quality brings a remunerative price. A 10 per cent increase in quantity by means of adulteration may cut the price in two, or may result in an oil which can not be sold at any price. The greatest advance in the ylang-ylang oil industry will take place when the distillers own their groves of trees and can select only ripe, yellow flowers for distillation. This fact is emphasized quite strikingly by the following experiment:

Fifty-four and five-tenths kilos (120 pounds) of extra fine flowers, one-half of which were perfectly yellow and ripe, were distilled with steam in the usual manner and the following fractions were obtained:

Number 1: 55 cubic centimeters; specific gravity, $\frac{30^\circ}{4^\circ}=0.960$; $A\frac{30^\circ}{D}=-19.8^\circ$; $N\frac{30^\circ}{D}=1.4865$; ester number, 178.

Number 2: 33 cubic centimeters; specific gravity, $\frac{30^\circ}{4^\circ}=0.959$; $A\frac{30^\circ}{D}=-26.5^\circ$; $N\frac{30^\circ}{D}=1.4914$; ester number, 160.

Number 3: 90 cubic centimeters; specific gravity, $\frac{30^\circ}{4^\circ}=0.954$; $A\frac{30^\circ}{D}=-34.6^\circ$; $N\frac{30^\circ}{D}=1.4956$; ester number, 154.

Number 4: 80 cubic centimeters; specific gravity, $\frac{30^\circ}{4^\circ}=0.942$; $A\frac{30^\circ}{D}=-53.4^\circ$; $N\frac{30^\circ}{D}=1.5020$; ester number. 113.

Tubes numbers 1, 2 and 3 united gave the following constants: Specific gravity, $\frac{30^\circ}{4^\circ}=0.958$; $A\frac{30^\circ}{D}=-27.0$; $N\frac{30^\circ}{D}=1.4910$; ester number, 169.

The total oil obtained was 258 cubic centimeters, which is 264 grams, corresponding to a yield of 0.45 per cent.

This yield was nearly twice the normal amount and the quality of the oil was very high, as was shown not only by the analytical figures given above, but also was confirmed by the opinions of Manila experts to whom it was submitted.

I believe these experiments indicate that 200 kilos of ripe, yellow flowers will give 1 kilo of a better quality of oil than will 400 kilos of the class of poor, mixed flowers used at the present time. It is a well-known fact of plant physiology that the odoriferous substance is present in the flower in greatest abundance and in finest quality at the time when it is mature and ready for pollination. No doubt, in the course of time much can be done toward improving the yield and quality of ylang-ylang oil by intelligent plant selection. Such work requires much patience and at present there are absolutely no data available save a general opinion that the ylang-ylang trees of the wild mountain regions are not as fragrant as the cultivated ones of the lowlands.

Fifty-four and five-tenths kilos of the same flowers were also distilled in a vacuum of 100 millimeters, an exceedingly slow operation. There were obtained 32 cubic centimeters of oil of a very good quality, with the following properties: Specific gravity, $\frac{30^\circ}{4^\circ}=0.949$; $A\frac{30^\circ}{D}=36.1$; $N\frac{30^\circ}{D}=1.4940$; ester number, 138.

The low yield is due to the fact that the only apparatus available had the vacuum pipe opening directly into the oil receiver, with only a comparatively short condenser above, and as a consequence most of the oil was lost by volatilization.

THE COMPOSITION OF YLANG-YLANG OIL.

The chemical composition of ylang-ylang oil has been pretty well established through the labors of many chemists.

Gal[6] found no aldehydes or ketones, but benzoic acid as esters of unknown alcohols. Flückiger,[7] correctly names the tree from which ylang-ylang oil is obtained and gives a good historical résumé concerning the oil and its introduction into Europe. He found in the oil a very small amount of benzoic acid, acetic acid and unidentified phenols (from the color reactions with ferric chloride) and suspected the presence of an aldehyde or ketone.

He obtained a very small amount of a precipitate with sodium bisulphite. He was unable to identify any of the alcohols from the oil. There would seem to be some doubt as to whether Flückiger studied a genuine sample of ylang-ylang oil, as the esters of benzoic acid are so abundantly present that the acid is separated in quantity with the greatest of ease. Reychler[8] found benzoic and acetic acids, linaloöl, geraniol and cadinene. Darzens[9] found methyl alcohol, *para*-kresol, benzoic and acetic acids and considered that the *para*-kresol was present as the acetate, for he states that *para*-kresol acetate has an odor somewhat like that of ylang-ylang oil. The final and most exhaustive researches on this perfume oil are due to the commercial houses, especially to Schimmel & Company,[10] whose results are embodied in a patent for artificial ylang-ylang oil.

A rational method of analysis of this oil should, if possible, be founded on its composition, and therefore we have undertaken studies in this direction and have succeeded in adding two new substances, formic acid and safrol (isosafrol), to the list of the known constituents of the ylang-ylang oil.

Experiment 1.—One hundred grams of first-grade ylang-ylang oil were taken; its constants were as follows: Specific gravity, $\frac{30^\circ}{4^\circ}=0.921$; $A\frac{30^\circ}{D}=-40.7$; $N\frac{30^\circ}{D}=1.4825$; ester number, 108.

This oil gave only a very faint reaction with ferric chloride at the contact zone, due to methyl salicylate, showing that the phenols were combined. It is interesting to note that none of the oils I have handled gave a strong color reaction with ferric chloride, and therefore the possibility suggests itself that the ageing of the oil causes a small amount of hydrolysis of the phenol-ethers, for most European observers have obtained pronounced color reactions with ferric chloride. The oil I used was more than neutralized with 0.1 cubic centimeter of $\frac{N}{10}$-caustic soda. All good ylang-ylang oils are neutral.

The oil was heated to 100° in a sealed tube with 15 grams of sodium hydroxide, dissolved in 30 cubic centimeters of water, for eight hours. At the end of this time a considerable amount of solid has separated; there was no pressure in the tube. The contents was dissolved in water and ether, the etherial layer separated, the aqueous portion well shaken with ether and the ether several times shaken out with small amounts of water so as to separate the alcohols soluble in that medium, the water being always added to the original alkaline solution. The latter was now distilled with steam and the distillate treated with benzoyl chloride according to Baumann-Schotten, 1.2 grams of methyl benzoate being obtained in this manner. A slight excess of dilute sulphuric acid was now added to the alkaline solution in the distilling flask and the whole was then extracted with ether, the latter being shaken out with small portions of water to remove acids soluble in that medium, these extracts being added to the aqueous portions. This was now distilled with steam, the distillate on titration with standard alkali showed 5.54 grams of volatile acids calculated as acetic. The barium and silver salts of the acids were prepared from this distillate and analysed.

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[6] *Compt. rend. Acad. d. sc., Par.* (1873), **76,** 1482.

[7] *Arch. d. Pharm.* (1885), **18,** 24.

[8] *Bull. Soc. Chim.* Paris (1894), **11,** 407, 546, 1057.

[9] *Ibid.* (1897), **27,** 83.

[10] D. R. P. 142, 859 Class 23, *a.* Schimmel & Company, semiannual report, October 1901 (English edition), p. 53.

I. 0.6916 grams barium salt gave 0.6466 gram barium sulphate.
II. 0.5195 grams barium salt gave 0.4872 gram barium sulphate.

	Found (per cent).	Calculated (per cent) for	
		$Ba(C_2H_3O_2)_2 2H_2O$	$Ba(CHO_2)_2$
I. Ba.	55.06	48.7	60.7
II. Ba.	55.10	....	....

I. 0.2065 grams silver salt gave 0.1897 gram AgCl
II. 0.2050 grams silver salt gave 0.1885 gram AgCl

	Found (per cent)	Calculated (per cent) for	
		$AgC_2H_3O_2$	$AgCHO_2$
I. Ag.	69.1	64.6	70.58
II. Ag.	69.1	....	....

This aqueous solution of the acids reduces potassium permanganate at once, and readily converts mercuric to mercurous chloride. These results, taken in conjunction with the analytical data and the fact that it was impossible to obtain a white silver salt, leave no doubt but that formic acid was present. The figures obtained for the silver salt are naturally different from those for the barium compound because of the slight reduction to metallic silver caused by the formic acid.

The etherial solution containing the acids not soluble in water was now repeatedly extracted with small portions of a solution of sodium carbonate. In this manner there were isolated 9.6 grams of solid acids having the appearance of benzoic and giving a test for salicylic acid with ferric chloride. The benzoic and salicylic acids were separated by conversion of the salicylic acid into the very insoluble dibromsalicylic acid. 0.6 gram, melting at 221° (found, bromine, 57 per cent; calculated, 57.4 per cent) sufficient water being used to keep the benzoic acid in solution.[11] The remaining acid, after extraction and one crystallization from ligroin was 7.7 grams of pure benzoic acid melting at 121° to 122°. After removing the acids, 0.9 gram of phenols having an odor resembling that of isoeugenol and giving a green color with ferric chloride was isolated.

A methoxyl determination according to Zeisel gave the following numbers: 0.92 gram of oil gave 0.1405 gram silver iodide equivalent to 0.031 grams of CH_3. This would represent 0.99 per cent of the total oil or 0.66 grams CH_3OH which would give 2.02 per cent of the total oil as CH_3OH. It would require 2.5 grams of CH_3OH to form the methyl esters with the 9.6 grams of solid acids which were found.

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[11] Sharpe: *Ztsch. f. An. Chem.* (1893), **32**, 107.

The neutral portion of the saponification product distilled *in vacuo* gave the following fractions:

Number 1: 37 grams; B. P. 90° to 120° at 37 mm., $A^{30°}_{D} = -16.5$; $N^{30°}_{D} = 1.478$.

Number 2: 15.5 grams; B. P. 120° to 130° at 34 mm.; $A^{30°}_{D} = -31.2°$; $N^{30°}_{D} = 1.4797$.

Number 3: 17.5, grams; B. P. 130° to 150° at 30 mm.; $A^{30°}_{D} = -77.7°$; $N^{30°}_{D} = 1.4943$.

Number 4: 9.5 grams of resinous residue.

Treatment of fraction 1 with dilute, aqueous potassium permanganate gives benzoic acid melting at 122°, thus proving the presence of benzyl alcohol in this fraction.

The above results gave the composition of ylang-ylang oil as follows:

Component.	Per cent.
Neutral	81.50
Formic and acetic acids	5.54
Benzoic acid	9.00
Salicylic acid	0.60
Methyl alcohol	2.02
Total	99.56

Several attempts were made to isolate an aldehyde from ylang-ylang oil, as treatment of the oil with fuchsine and sulphur dioxide gave the color change characteristic of aldehydes, but phenylhydrazine shows no trace of reaction with the oil and on shaking thoroughly with freshly prepared and very active sodium bisulphite no such bodies could be isolated by the usual means; so that no more than a trace of aldehydes can be present in ylang-ylang oil. The work with 100 cubic centimeters was repeated with 1,000 grams of ylang-ylang oil in the hope that the decomposition of larger quantities would lead to the discovery of constituents heretofore not recognized.

Experiment 2. One thousand grams of good quality ylang-ylang oil from Nueva Caceres and having the following constants: Specific gravity, $\frac{30°}{4°} = 0.912$; $A^{30°}_{D} = -45.6°$; $N^{30°}_{D} = 1.4920$; ester number, 100, were used.

The oil was saponified in four lots, the first three by using 200 cubic centimeters of oil and 35 grams of potassium hydroxide dissolved in 150 cubic centimeters of 92 per cent alcohol the final one of 497 cubic centimeters of oil was hydrolyzed with 60 grams of potassium hydroxide dissolved in 400 cubic centimeters of the same solvent. Within a few minutes after the alcoholic potash was added the oil became filled with crystals of the potassium salts of the acids. No other solids separate. This was proved by a special experiment with a sample of first quality oil in which the solid formed by saponification was filtered, well washed with absolute ether and decomposed by dilute acids, the resulting substances being benzoic, salicylic, formic and acetic acids as well as a very small quantity of phenols.

The contents of the first three flasks were completely saponified by two hours' heating on the steam bath with a reflux condenser, the last fraction by one week's standing at room temperature. The procedure used in working up the product was like that given in the details of experiment 1.

The solid, acid portion: The total amount was 91 grams. The benzoic and salicylic acids were separated by means of their esters, salicylic methyl-ester being soluble in a 10 per cent sodium hydroxide solution. The methyl esters after this separation, boiled almost constantly at 195° and 224°, respectively, so that there would seem to be no reason to suspect any acids other than benzoic and salicylic to be present in the solid, acid portion. The total quantities were 6 grams of salicylic acid and 85 of benzoic.

The soluble acid portion: The alkaline, aqueous solution was first evaporated to a small bulk in order to remove all neutral volatile substances. It was then rendered acid with dilute sulphuric acid, and the volatile acids were distilled. The total volatile acids, calculated as acetic acid, were 63.5 grams. Barium salts were prepared and gave the following analytical data:

0.6995 gram barium salt gave 0.6521 gram barium sulphate

	Found (per cent).	Calculated (per cent) for	
		$Ba(C_2H_3O_2)2H_2O$	$Ba(HCO_2)_2$
Ba	54.97	48.70	60.3

Naturally, the percentage of barium found gives no clue to the relative proportions of the two acids present because of the differing solubilities of the salts, the acetate of barium being more soluble in water than the formate. The solution of the soluble acids reduces potassium permanganate and also mercuric chloride, and as neutral salts have been prepared from the solution with a greater percentage content of barium than is in the acetate, the only conclusion is that formic acid is present.

The formic acid was estimated according to the method of H. C. Jones[12] by heating with an excess of standard potassium permanganate in the presence of an alkaline carbonate, then adding a known excess of oxalic acid, and titrating back with potassium permanganate. The result showed that from the original kilo of oil there were separated 41.2 grams of acetic and 17.1 grams of formic acid.

A portion of the barium salts of these acids was treated with ethyl alcohol and concentrated sulphuric acid; the resulting esters possessed the characteristic odor of ethyl acetate and formate and no odor was noted suggesting the presence of acids other than those named. Reychler[13] states that he has observed a pronounced, rancid odor in the aqueous mother liquors, suggesting small amounts of the higher fatty acids. I could confirm his observation and I believe there is a trace of valerianic acid in the mother liquor.

The phenol fraction.—This was in all 10 grams. The phenols gave a green color with ferric chloride and an odor resembling that of kreosol (the 3-methyl ether of homopyrocatechin ($C_6H_3(CH_3)^1(OCH_3)^3(OH)^4$) was noted in this fraction. There was separated from this fraction according to the method of Baumann-Schotten by the action of benzoyl chloride a small amount of *para*-kresol benzoate, melting at 77° and isoeugenol is also present. I have not attempted thoroughly to study the phenol fraction because of its small amount and because it has been well identified by Schimmel & Company.[14]

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[12] *Am. Chem. J.* (1895), **17**, 539.

[13] *Loc. cit.*

The neutral fractions after shaking out the alcohol as thoroughly as possible, was dried over anhydrous sodium sulphate, as calcium chloride was difficult to remove, both because of the presence of ethyl alcohol and because of the solid compounds which may be formed with benzyl alcohol and with geraniol.

The total neutral oil weighed 808 grams; it was subjected to three careful fractionations *in vacuo*, using a column of glass beads in a high-necked distilling flask. The fractions obtained, together with their physical constants, are given in the following table:[15]

TABLE V.—*Fractions obtained by distilling the neutral oils left after saponifying 1,000 grams of ylang-ylang oil and removing other constituents.*

No.	Boiling point.		Sp. gr. $\frac{25^\circ}{4}$	$A\frac{25^\circ}{D}$	$N\frac{25^\circ}{D}$	Amount (grams).	Percentage of hydroxyl.
	15 mm.	760 mm.					
1	57°- 68°	160°-170°	0.880	+11.5	1.4807	8.1	0.5
2	68°- 75°	170°-175°	0.903	+ 1.2	1.4851	17.6	1.4
3	75°- 80°	175°-180°	0.913	− 5	1.4850	16.4	2.2
4	80°- 85°	180°-185°	0.902	− 8.9	1.4808	19.1	8
5	85°- 90°	185°-190°	0.889	−12.8	1.4750	18.3	11.07
6	90°- 95°	----------	0.8885	−15.4	1.4750	71	11.6
7	95°- 98°	----------	0.8895	−15	1.4764	124	11.6
8	98°-105°	----------	0.9131	−11.7	1.4862	25	11.2
9	105°-115°	----------	0.9045	−10.5	1.4869	32	10.3
10	115°-125°	----------	0.8894	−24.2	1.4896	61	8.4
11	125°-130°	----------	0.9065	−64.4	1.5060	79	0.5
12	130° (con.)	----------	0.8926	−74.4	1.5055	117	0.13
13	Total except residue					588.5	----------
	Residue, pleasant smelling tar and polyterpenes					172.0	----------
	Total					760.5	----------

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[14] *Loc. cit.*

[15] This method of fractionation with a column of glass beads has been used by Michael and by Freer for many years and gives exceedingly satisfactory results. For a small flask, a test tube is drawn out to a capillary and the upper end so cut off as to rest rather snugly in the neck of the distilling flask. Glass beads are then filled in to within 1 or 2 centimeters of the exit tube. A properly prepared tube gives a continuous stream of small bubbles from its capillary end because of the small reservoir just below the glass beads, so that the distillation *in vacuo* proceeds smoothly and without bumping. If it is desired to introduce a stream of air or other gas through a capillary, as it is advisable to do when dealing with large quantities of oils, the beads rest on a piece of platinum gauze supported by a test tube or suitable bent rod. The separation effected by the glass beads because of the many points of glass contact is surprisingly efficient, probably better than with bulb forms of fractioning apparatus, and the vapor does not need to be driven nearly as high as with the older forms of apparatus.

The figures given for the percentage of hydroxyl in the seventh column of the table were obtained by the Grignard reaction, in accordance with the method proposed by Zerewitinoff.[16] In using this method, methyl iodide dissolved in amyl ether is treated with magnesium and the amount of methane given off by adding an alcohol to the resulting magnesium methyl iodide is measured. This represents the amount of hydroxyl in the added compound, the reaction being:

$$ROH+CH_3MgI \longrightarrow CH_4+ROMgI.$$

The method is exceedingly convenient after the reagent is prepared, it is quick and uses only about 0.2 gram of oil. It bids fair to displace the older method of obtaining the acetyl number. It is well known that with many alcohols, as for example with linaloöl, the standard methods give an acetyl number many percent too low. This new method promises to give more accurate numbers and is so exceedingly convenient that we are now testing it thoroughly. The results I have obtained in my first series are as follows:

	Found hydroxyl (per cent).	Calcuted hydroxyl (per cent).
Linaloöl	10.95 11.4 11.2 11.3 11.1 11.1	11.04
Geraniol	11.3 11.4 11.2	11.04
Benzyl alcohol	15.8 15.7 15.9 15.6	15.74

The formula used in calculating the percentage of hydroxyl is as follows:

$$X \text{ (per cent OH)} = 0.0764\frac{V}{S}$$

where V=volume of CH_4 at 0° and 760 millimeters and S is the weight of substance taken.

Fraction 1 always presented an odor very much resembling that of amyl or hexyl alcohol. By treating this fraction with benzoyl chloride according to the method of Baumann-Schotten and redistilling *in vacuo*, this odor is removed, the fraction then assumes the odor of terpenes and I was able to obtain a few crystals of pinene nitrosylchloride melting at 103° from this low-boiling portion. This, together with the optical rotation of this fraction would indicate the presence of *d*-pinene in small quantity. The boiling point of the first three fractions indicates that very little pinene is present. A very small percentage of hydroxyl was also found, so that the major part probably consists of other terpenes. The presence of limonene could not be proved. As these terpenes are of no great importance in determining the odor of ylang-ylang oil, no further attempts were made to identify them.

[16] *Ber. d. chem. Ges.* (1901), **40**, 2023.

Fractions 1 to 5 seem to consist of a mixture of terpenes with linaloöl and benzyl alcohol, with possibly a small amount of amyl or hexyl alcohol. A special experiment made to separate the terpenes from the alcohols by means of the Grignard method according to the equation

$$CH_3MgI+C_{10}H_{18}OH \longrightarrow C_{10}H_{18}OMgI+CH_4$$

demonstrated that linaloöl as well as the alcohols of ylang-ylang oil give addition products which are soluble in ether, so that no separation was possible.

Fractions 6 and 7.—These fractions possess an odor much like that of linaloöl and in addition another, sweet one, is present. Oxidation of 9 grams of the united fraction with dilute potassium permanganate gave 1.2 grams of benzoic acid melting at 121°. This corresponds to 13.3 per cent of benzyl alcohol.

A small portion of these fractions was oxidized with potassium bichromate and dilute sulphuric acid, and by this means the odors of benzaldehyde and of citral were obtained.

The fractions 6 and 7 were also heated with finely powdered calcium chloride for one hour on a steam bath and then kept in a cool place for twenty-four hours. A solid compound with calcium chloride separated, this was filtered with the aid of a pump, and well washed with ether. Twenty-nine grams of an oil boiling between 200° and 206° at ordinary pressure were obtained on decomposing this addition product with water. This body had the odor of benzyl alcohol and proved to be the latter almost in its entirety by conversion into benzyl acetate, and also by obtaining an 85 per cent yield of benzoic acid by oxidation. The liquid not entering into combination with calcium chloride, proved itself to be almost pure linaloöl, as is shown by the following constants: Specific gravity, $\frac{30^\circ}{4^\circ}=0.8586$; $A\frac{30^\circ}{D}=-16^\circ$; $N\frac{30^\circ}{D}=1.4655$; boiling point 190° to 195° at ordinary pressure. The odor of this portion was identical with that of linaloöl, and citral was produced from it by oxidation with potassium bichromate.

Fraction 8.—This portion was separated into 10 grams of benzyl alcohol, 11 grams of linaloöl, and 3 grams of an oil which solidified with calcium chloride, boiled at a higher point than benzyl alcohol and therefore from its odor and the formation of an addition product with calcium chloride it was determined to be geraniol.

Fraction 9.—This fraction, on treatment with powdered calcium chloride immediately became hot and solid. This method of separation gave 8 grams of an oil not acted upon by calcium chloride and having a refractive index of $N\frac{30^\circ}{D}=1.5131$. This portion had the odor of safrol. Oxidization with acid potassium bichromate gave the odor of heliotrope. The oil which was separated from the calcium chloride compound possessed a pronounced geraniol odor, boiled at 108° to 115° at 10 millimeters; specific gravity $\frac{30^\circ}{4^\circ}=0.881$; $N\frac{30^\circ}{D}=1.4821$.

Fraction 10 was similarly separated into 12 grams of geraniol, a small amount of safrol, and into sesquiterpenes.

Fractions 11 and 12 consisted almost entirely of sesquiterpenes, among which cadinene is present, as a small yield of cadinene hydrochloride melting at 117° was obtained on treating 10 grams of this fraction, dissolved in ether, with dry hydrogen chloride.

SUMMARY OF RESULTS.

Ylang-ylang oil is thus seen to contain the following substances: Formic, acetic, valerianic (?), benzoic and salicylic acids, all as esters; methyl and benzyl alcohols; pinene and other terpenes, linaloöl, geraniol, safrol, cadinene and other sesquiterpenes; eugenol, isoeugenol, *p*-kresol, probably as methyl ethers; and kreosol.

Many of the esters which could possibly be formed by a combination of the isolated alcohols and acids have been prepared in this laboratory in order to become familiar with their properties and especially with their odor. It seems of interest to give notes in regard to their properties.

Benzyl salicylate.—No record appears in the literature of the preparation of this compound. It is made as follows: 27.4 grams of salicylic acid are neutralized with 11.2 grams of potassium hydroxide and the solution evaporated to dryness. This potassium salt is heated to 200° for four hours in sealed tube with 25 grams of salicylic acid and 25.2 grams of benzyl chloride. On opening the tube no pressure is observed and all of the benzyl chloride has disappeared. There is obtained 26 grams of a colorless, viscous oil boiling between 186° and 188° at 10 millimeters. The odor is slightly aromatic and pleasant, but not powerful. The oil, after three months in the ice box, has not solidified. Five grams of the ester saponified with alcoholic caustic potash, gave 2.4 grams of salicylic acid melting at 155° (recrystallized from water), and the acid was further identified by conversion into the methyl ester. There also resulted 2 grams of benzyl alcohol, boiling at 204° and converted into benzyl acetate.

Benzyl benzoate has been prepared by the action of sodium benzylate on benzaldehyde. The method used in this laboratory was as follows: 50 grams of sodium benzoate, 50 grams benzoic acid, and 43 grams of benzyl chloride were heated on a reflux condenser in a metal bath at a temperature of 200° for two hours. There resulted 46 grams of oil boiling between 315° and 320°. Benzyl valerianate and benzyl butyrate were also prepared by the same general method, the yield being very good. The method formerly in use, which employed the lead salts, did not give good results.

Benzyl valerianate can also be prepared in almost quantitative yield by the action of valeryl chloride on sodium benzylate. The properties of this body correspond to those given in the literature. The odor of this ester is not as sweet as is that of benzyl acetate, it being more like that of fruit. It is almost certain that there are traces of benzyl valerianate in ylang-ylang oil.

Benzyl-methyl ether is obtained in almost quantitative yield by heating benzyl chloride with a slight excess of sodium methylate dissolved in methyl alcohol, in a sealed tube to 120° for two hours. The transformation is not complete if these same substances are heated only in an oil bath on a reflux condenser, and in addition the benzyl-methyl ether always contains chlorine.

Benzyl-methyl ether is a colorless oil boiling between 166° and 168°; it has an almost nauseatingly sweet odor. There is probably a very small amount of it present in ylang-ylang oil.

Benzyl formate.—Benzyl chloride is heated with a slight excess of potassium formate dissolved in formic acid in a sealed tube at 140° for two hours. The body boils at 84° to 85° at 10 millimeters pressure and has an odor sweeter than that of benzyl acetate, but much like it. The yield is over 90 per cent by this method. It is necessary to use a sealed tube, as benzyl chloride does not dissolve in absolute formic acid at 100°.

Geraniol-methyl ether.—This body was prepared from the sodium derivative of geraniol and methyl iodide. It is a colorless oil, boiling between 100° and 105° at 10 millimeters and at 208° to 212° at ordinary pressure. Its odor resembles that of geraniol, but it is more like that of grass.

Linaloöl-methyl ether is prepared in the same manner as geraniol-methyl ether, it boils between 189° and 192°, and its odor is not very different from that of linaloöl, it is not as fragrant as that substance.

Geraniol benzoate was prepared by the Baumann-Schotten method, using 10 grams of geraniol and 10 grams of benzoyl chloride. The oil boils between 198° and 200° at 15 millimeters. It has quite a pleasant odor, much like that of some of the higher boiling fractions of ylang-ylang oil.

SYNTHESIS OF YLANG-YLANG OIL.

An attempt was made to prepare an artificial product to test the accuracy of these studies on the composition of ylang-ylang oil. The following substances were used:

Methyl benzoate; benzyl acetate and formate; benzyl methyl ether (trace); benzyl valerianate (trace); methyl salicylate; benzyl benzoate; cadinene; safrol; isoeugenol-methyl ether; eugenol; kreosol; methyl anthranilate (trace); *p*-kresol-methyl ether; *p*-kresol acetate.

With these ingredients a mixture was compounded smelling deceptively like good ylang-ylang oil. The fluorescence of ylang-ylang oil, which is always present to a greater or lesser degree, is probably due to the presence of methyl anthranilate.

The above work, and that of others demonstrates that ylang-ylang oil has a composite odor, derived from that of many constituents. While it is possible to make a very good artificial ylang-ylang oil, I do not believe that distillers of the best quality of ylang-ylang oil have much to fear from this competition, as the odor of a first-class oil seems to have more permanence than that of the artificial product. This is a result, I believe, of the presence of sesquiterpene alcohols and fragrant resins in the former.

Work on the physical constants and methods of analysis of ylang-ylang oil will be continued as fast as material is available. The future determinations, in addition to the constants given in this paper will include the acetyl number, and if possible a phenol number. The acetyl number is undoubtedly of much importance, as is evidenced from the large percentage of fragrant alcohols found in ylang-ylang oil. Our first quality of oil gave an acetyl number of 74, while a second quality only gave one of 42. We will also in our future work use a constant equal to the sum of the ester and acetyl numbers, thus representing the total amount of alcohols and esters in the oils. Such a number for the last mentioned first quality oil was 174 as compared to 110 for the second grade product. We believe we will thus be able from a few simple analytical determinations to draw many conclusions as to the composition of any ylang-ylang oil presented to us and thus be able to judge of its quality.

THE COMPOSITION OF HORLICK'S MALTED MILK.

By George F. Richmond and W. E. Musgrave.
(From the Chemical and Biological Laboratories, Bureau of Science.)

Since the publication of our monograph[1] on "Infant Feeding and its Influence upon Infant Mortality in the Philippine Islands" our attention has been directed to errors in the quoted analysis of Horlick's malted milk given on pages 375 and 378 and also our observation on page 374 that the greatest objection to malted milks as infant foods lies in the large amount of insoluble carbohydrates which they contain. The analysis of Horlick's malted milk therein quoted was taken from Chapin[2] who in turn quotes McGill,[3] who reported upon 103 samples representing 22 different brands of infant and invalid foods as found on the Canadian market. His results upon the malted milk in question are the mean of nine separate analyses made by himself and others and are as follows:

	Per cent.
Moisture	2.55
Fat by petroleum ether	1.41
Loss to alcohol and water	63.87
Total albuminoids N×6.25	14.00
Starch fiber, ash, etc., by difference	15.68
Ash	3.57

The manufacturers of Horlick's malted milk maintain, first, that the percentage of fat, 1.41, as quoted is grossly in error and refer to analyses by Smith[4] who found over six times as much, namely, 8.75 per cent, Chittenden[5] who encountered at least 8 per cent, and to European workers, including the British Analytical Control and the Glasgow Corporation, who reported 8.85 and 8.8 per cent respectively; second, that the proteid content, 14 per cent, as found by McGill is also below the true value of 16 to 17 per cent claimed and based upon the analyses covered by the above references; third, that 0.05 per cent represents more nearly the true content of insoluble carbohydrates in their product. Manifestly such variation in the percentages of the important ingredients of an established food stuff are well worth inquiry. In the interest of fairness to the manufacturers and ourselves, therefore, we determined to make a personal examination of the product as found on the Manila market.

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[1] *This Jour. Sec. B* (1907), **2**, 4.

[2] Theory and Practice of Infant Feeding, 2d ed. 1904.

[3] Bull. **59**, Laby. Int. Rev. Dept., Canada.

[4] Holt on Infancy and Childhood, 1902.

[5] *Dietetic and Hygiene Gazette*, 1896.

It has been known for some time that Adam's Soxhlett extraction method for the estimation of fats failed in the presence of considerable quantities of carbohydrates and that some other method of procedure was necessary in order to obtain a maximum yield of fat in sweetened condensed milks, milk powders and malted milks. Modifications of the Soxhlett method such as drying a highly diluted aqueous solution of the material on large surfaces, interstratifying the dried powder with some inert substance such as sand or asbestos or finely grinding the dried powder with powdered glass, before extraction with organic solvents, will increase the yield somewhat. The percentage of fat in Horlick's malted milk determined in this laboratory both before and after grinding the dried powder with powdered glass was 1.78 and 2.50 per cent respectively. The well-known Babcock volumetric method is also not suitable for such products because of the charring action of concentrated sulphuric acid on the carbohydrates. Leach's[6] modification of the Babcock process, which consists in separating the sugars from the fats and proteids by means of copper sulphate before the addition of sulphuric acid, is not very satisfactory when applied to malted milks because of the difficulty of accurately sampling the material and in reading the volume of fat obtained.

Several trials on Horlick's malted milk with Leach's modification of the Babcock process gave an average of 8.32 per cent of fat.

Cochran,[7] with a modified Babcock bottle and by the use of equal volumes of 80 per cent acetic acid and concentrated sulphuric acid, claims that the charring action is much less than when concentrated sulphuric acid is used alone. Instead of centrifugating he separates the fat by means of ether, which is evaporated before the volume of fat is taken. Here again the same difficulties in introducing a very hygroscopic powder into the narrow-neck flask and in reading the correct volume of fat are encountered. However, it is only fair to state that our attempts to obtain concordant results with Cochran's method were made with the ordinary Babcock bottle which does not provide for sufficient means of escape of the ether vapor. In this laboratory much better results were obtained by precipitating the proteids in malted milk with acetic acid and heat and by subsequent extraction of the dry precipitate with petroleum ether.

Our exact procedure was as follows: A 1-gram sample of the air-dry powder was transfered to a small breaker, 25 cubic centimeters of water added and the whole stirred to a completely homogeneous solution. It was then acidulated with 5 cubic centimeters of 1 per cent acetic acid and heated on a steam bath until the albuminoids separated in coarse floccules, after which it was filtered through a weighed platinum Gooch crucible and washed with water until the washings were free from carbohydrates. After drying, the crucible and its contents were transfered to a direct extraction apparatus and exhausted with pretroleum ether, The fat was then determined from the loss of weight of the crucible or from the weight of the petroleum ether extract. A mean of four determinations by this method gave 8.18 per cent of fat. That all the fat is carried down and retained in the Gooch was evidenced by negative tests for fat in the clear filtrate.

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[6] *Jour. Am. Chem. Soc.* (1900), 22, 589.

[7] *Jour. Am. Chem. Soc.* (1905), 27, 906.

Trillat and Sauton [8] have described a new method for the determination of proteids in milk which is identical with the procedure given above for the determination of fat, with the exception that they add 5 drops of commercial formaldehyde to the diluted milk before acidulating with acetic acid; they also extract the dried precipitate with acetone instead of ether. They claim that no proteids could be detected in the filtrate by any of the ordinary reagents.

It was hoped that the process as followed would also serve for the estimation of the total albuminoids in malted milks, but it was found that the filtrate contained at least one-half of the total proteids of the original powder, furthermore that the fat-free residue left in the Gooch crucible contained about 2½ per cent of nonnitrogenous matter calculated on the original weight of malted milk dissolved. The nonnitrogenous matter thus found was not due to incomplete removal of soluble carbohydrates, nor was it mineral in nature, for the ash content of the filtrate accounted for the total amount of ash found in the malted milk by direct estimation; therefore, malted milk undoubtedly contains nonnitrogenous organic matter insoluble in excess of boiling acidulated water to that extent.

The detailed results of our analysis of Horlick's malted milk is given in the following table and represents the mean of four separate analyses:

	Per cent.
Moisture (loss at 100° C.)	4.03
Fat (by petroleum ether)	8.18
Total albuminoids nitrogen×6.25	16.64
Total soluble carbohydrates (loss to boiling water)	64.47
Insoluble nonproteid organic matter, starch fiber, etc.	2.60
Mineral matter	4.08

Summary: First, the comparatively high moisture content is readily explained by the greater relative humidity of this climate; second, the samples examined in this laboratory contain at least 8 per cent of fat.

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[8] *Bull. Soc. Chim.*, **39**, 906.

The fat content of a prepared food in which cow's milk is an important ingredient will be subject to considerable variation, but amounts approximating 9 per cent as reported by others are probably too high, due in most cases at least to approximate volumetric methods of estimation; third, the malted milk contains 2.6 per cent of nonnitrogenous organic matter insoluble in hot water which reduces the total soluble carbohydrates from 67.63 per cent (the average of three determinations from different sources) to 65.03 per cent which is in close agreement with our results and which more nearly represents the actual amount of soluble carbohydrates present; fourth, the malted milk in question contains between 16 and 17 per cent of proteids which figures fully substantiate the claims of the manufacturers in this respect; fifth, the product contains about 4 per cent of inorganic salts, which figure is also in close agreement with the average of previous findings.

EDITORIAL.

THE RELATIONSHIP BETWEEN THE EXTERNAL APPEARANCE AND THE ASH CONTENT OF PHILIPPINE COAL.

A quantity of coal from a mine south of Sydney, Australia, was sent to this Bureau in 1907 for test. The coal was fairly compact and for the most part with a hackly fracture. It was markedly characterized by alternating dull and lustrous bands parallel to the bedding planes. The lustrous bands were usually not over a few millimeters in thickness, while the dull layers were many times that. The luster of the lustrous bands was quite brilliant, approaching the vitreous appearance of obsidian. It occurred to me that the difference in the brilliance of the bands might be due to the content of earthy matter. The two were carefully isolated and the ash determined as follows:

Dull portion (per cent).	Lustrous portion (per cent).
12.1	2.6

These numbers show that without doubt a large part of the difference in luster is due to the ash content.

I do not think that coals from entirely different sources are to be compared, but it is quite probable that the luster of coal from the same vein or same field may vary inversely as the content of earthy matter.

I have already called attention[1] to the striking similarity between all the coals thus far discovered in the Philippine Islands, and I have arranged the record of a number of samples of these together with some from Australia in the order of their descreasing ash content, in the following table:

Philippine coals arranged in order of decrease in ash content.

Source of coal.	Ash (per cent).	Luster of the coal.
Tayabas, Mauban	31.50	Very dull.
Negros, near Cadiz	18.00	Dull to sublustrous.
Batan Island	14.70	Dull.
Negros	14.23	Dull to very lustrous, uneven.
Australia	12.55	Dull to lustrous, uneven.
Australia[a]	12.01	Dull.
Australia	9.99	Dull for the most part. Streak very lustrous.
Negros, Escalante	9.55	Sublustrous to lustrous.
Surigao	9.06	Sublustrous, uneven.

[a] Given above.

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[1] The Mineral Resources of the Philippine Islands, Bulletin of the Division of Mines, Bureau of Science, Manila, 1908.

Philippine coals arranged in order of decrease in ash content—Continued.

Source of coal.	Ash (per cent).	Luster of the coal.
Philippine Islands	7.86	Sublustrous.
Cebu, near Carmen	7.48	Do.
Philippine Islands	7.22	Sublustrous to lustrous.
Philippine Islands	6.95	Sublustrous.
Cebu, near Carmen	6.50	Sublustrous to lustrous.
Luzon, Rizal	6.20	Lustrous.
Polillo	6.00	Dull to lustrous.
Polillo, Vista de Burdeus	4.38	Sublustrous, uneven.
Cebu, Libing-bato	4.17	Lustrous.
Batan Island, Bett's	4.12	Sublustrous, uneven.
Cebu	3.81	Lustrous.
Zamboanga	3.77	Do.
Tayabas, Antimonan	3.70	Dull to lustrous, uneven.
Samar	3.49	Lustrous.
Cebu, near Carmen	3.28	Do.
Australia[a]	2.60	Very lustrous.
Batan Island, Military Reservation, coal seam No. 5	2.50	Lustrous.
Rock Spring, Wyoming	1.92	Sublustrous.
Mindoro, Bulalacao	1.61	Do.
Cebu, near Carmen	1.61	Lustrous.

[a] Given above.

These lusters of these coals were nearly all determined[2] at the same time, they are therefore comparable and show that to a marked extent they depend on the content of earthy matter.

Perhaps there are also other conclusions which may be drawn from the ash content of a coal. It is generally known that the value of a coal increases with the size and continues until egg size and lump are reached. It is also generally true that the heating power advances in the same manner, but by no means in the same proportion as the above factors. This increase is due, barring physical conditions, mainly to the diminished quantity of ash which may be seen from the following figures of Mr. Somermeier.[3] The sample was thoroughly air-dried and separated by sifting into various sizes and analyzed by the official method as noted below:

Size in fractions of an inch.	Moisture.	Volatile combustible matter.	Fixed carbon.	Ash.
$\frac{1}{80}$ and finer	2.05	35.54	59.66	*2.75*
$\frac{1}{40}$ to $\frac{1}{80}$	1.90	38.05	58.40	*1.65*
$\frac{1}{20}$ to $\frac{1}{10}$	1.70	38.55	58.35	*1.40*
$\frac{1}{10}$ to $\frac{1}{20}$	1.45	38.80	58.55	*1.20*
$\frac{1}{4}$ to $\frac{1}{10}$	1.15	39.05	58.20	*1.60*

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[2] *This Journal, Sec. A* (1907), **2**, 50.

[3] *J. Am. Chem. Soc.* (1906), **28**, 1008.

The greater percentage of moisture in the fine coal is probably accounted for by the phenomena of adsorption. The finer the coal the larger the surface exposed and consequently the greater the quantity of water abstracted from the air and held upon its surface.

ALVIN J. COX.

STARCH PRODUCTION IN THE PHILIPPINE ISLANDS.

The cassava plant (*Manihot utilissima* Pohl) is found in all parts of the Philippines. The Tagalog name is *camoting cahoy*. In the northern islands the tubers are extensively used by the natives as a food during times of need, while with the Moros it forms a staple article of diet. As all Philippine varieties of the plant contain considerable quantities of hydrocyanic acid, the tubers are not used as extensively for stock food as they should be, for the natives generally do not understand how to treat the plant so as to remove this poisonous acid. The problem of obtaining a good and cheap stock food is an exceedingly important one in the Philippines. Nothing appears to me so promising as cassava and the cowpea. The two plants should be grown together. The greatest demand which cassava makes on the soil is in nitrogen, which the cowpea supplies. By a suitable combination of the cowpea, rich in nitrogenous substances, the cassava roots, rich in carbohydrates, and coconut oil-cake, rich in fats, it is a simple matter to make up a first-class, well-balanced stock food. All these substances can easily be made available in the Philippines, so there is no necessity for the importation into the Islands of stock food from foreign countries. If the cassava is planted for its starch, or for alcohol manufacture, some other quick-growing legume such as mungo or peanuts, could be planted with it. These crops will not only pay well in themselves and add nitrogen to the soil, but they serve the further purpose of keeping out the weeds until the cassava is able to take care of itself.

With this introduction as to the best methods of handling cassava, it may be stated that in this plant the Philippines has the cheapest source of starch in the world, and there is only one other substance which at the present time seems able to compete with it as a source of alcohol, a product of which there is a large native supply, namely, the molasses residue from the crystallization of cane sugar. The cheapest alcohol manufactured on any large scale to-day comes from this source, being made in Cuba and Brazil and sold for 10 cents a gallon. Until the methods of alcohol manufacture from cellulose substances (sawdust, etc.) are perfected, the Philippines has in great quantity the two cheapest raw products for alcohol manufacture.

There are no reliable data on the right yield of cassava in the Philippines. In Mississippi and Florida, on good ground, 10 tons of roots are obtained per acre. The record of yields for this plant found in the literature runs from 4 to 200 tons per acre. In the Philippines the plant has never been raised on a large scale, although several companies are now planting it quite extensively. Plants abount a year old, selected at random from the district in the neighborhood of Zamboanga, Mindanao, averaged 25 pounds of roots each, which, planting 1 meter each way, would give a yield of 50 tons per acre. If 10 tons per acre can be obtained in the Southern States of America, with a possible growing period of from eight to nine months, it would seem to be perfectly safe to figure as much for virgin Philippine soils, with a growing period of twelve months. One acre of ground in the United States will produce on an average 40 bushels of corn containing 1,500 pounds of extractable starch. One acre of cassava in the Philippines will produce at least 10 tons of roots containing 5,000 pounds of extractable starch. If the fermentable matter is converted into alcohol, the comparison becomes even more favorable to the cassava, as the roots contain in addition to the starch, about 4 to 6 per cent of fermentable sugar, so that from the crop of 1 acre of this plant, over 400 gallons of 95 per cent alcohol could be manufactured. Alcohol can be made from cassava for about the same price as from corn and its manufacture from this substance costs in Peoria, Illinois, $0.032 gold per gallon. One can easily figure the price at which cassava alcohol can be sold and still leave a profit.

The cost of manufacturing starch from cassava is also essentially the same as from the potato, and it has been described in a paper soon to appear in the Philippine Agricultural Review by Dr. E. B. Copeland and myself. I shall not treat of it here. If a factory for manufacturing starch from the roots is not available, these may be ground up, dried and sifted, the cassava flour resulting having a starch content of 60 to 75 per cent. Some cassava meal, so prepared by pounding up the roots in a rice mortar and sun drying, has been kept in an open bottle in this laboratory for two years and shows no signs of decay. Dr. H. W. Wiley, of the Bureau of Chemistry, United States Department of Agriculture, quotes a price of 1⅓ cents, gold, per pound for such crude cassava meal. First-class cassava starch will probably average over 3 cents, gold, per pound, and pearl tapioca prepared from it, about one-half cent higher.

Heating, or very thoroughly washing, is necessary in preparing cassava starch products so as thoroughly to eliminate all the hydrocyanic acid. This acid is apparently present, combined with other substances, in the form of a glucoside, as we have many times noted that cassava roots which had stood until there was a slight decay, had a very powerful odor of this acid, while no such odor may be detected in the fresh root; hence I would recommend to agriculturists of these Islands that in feeding to hogs, the roots should be ground up and either washed many times with water, or better boiled with water into a starch paste.

The analyses of Philippine cassava tabulated below, show it to contain about the same percentage of starch as the same plant found in other parts of the world. The following two plants were from a plantation on Basilan Island, the analyses being made by Mr. Reibling:

Item.	I.	II.
Age of plant ________ months__	10	12
Weight of roots ________ grams__	10,872	14,360
Moisture ________ per cent__	54.6	54.7
Dry residue ________ do____	45.4	45.3
Commercially extractable.		
Air-dry starch ________ per cent__	27	26
Ash ________ do____	.81	.95
P_2O_5 ________ do____	.13	.13
HCN ________ do____	.24	.15
Total N as NH_3 ________ do____	.51	.58
K_2O ________ do____	.15	.18

The large increase in weight noted for twelve months as compared to ten months is worthy of attention, as I have been repeatedly told by Filipinos in many different parts of the Islands that if the plants are allowed to grow for from eighteen months to two years, the tubers will then be very large, weighing 80 to 120 pounds per plant.

Five and three-tenths kilos of cassava of unknown age, from Rizal Province, gave by grinding on a nutmeg grater, 1,350 grams air-dry starch (25 per cent) and 600 grams (11.3 per cent) of fibrous residue containing 64 per cent of starch. Experiment demonstrated that by grinding this fibrous residue dry in a mortar, a further 3.5 per cent of the total of starch could be obtained. However, under present-day conditions of cheap land and cheap labor in the Philippines, it is not good business policy to attempt to obtain any high extraction of the starch from the roots, as to extract this last few per cent costs relatively more than to remove the first 20 per cent of starch and the money can be used to better advantage in raising more roots.

One thousand three hundred grams of cassava roots (said to be 2 years old) were rasped on the machine described in the article referred to above, giving 400 grams of air-dry starch (30.77 per cent) or 27 per cent dry weight, and 110 grams of fibrous residue (8.4 per cent). The starch in this residue was 51 per cent.

Four thousand grams of tubers (age unknown) from Batangas Province, gave 1,050 grams of dry starch (26.2 per cent), and 345 grams of fibrous residue (8.5 per cent).

The above percentages are quoted as samples of the yield of starch which may be obtained in a commercial way from Philippine *camoting cahoy*. Other analyses made in this laboratory run from 24 to 30 per cent of starch and it seems reasonable to assume that 25 per cent of air-dry starch (14 to 18 per cent water) may be commercially extracted from the plant.

Samples of arrowroot (*Maranta arundinacea* Linn.) grown in the Islands contained from 18 to 22 per cent of starch. The plant is raised only as a food for hogs. It seems rather extravagant to feed to hogs one of the highest priced of starches.

Sincamas (*Pachyrhizus bulbosus* Britton) [*P. angulatus*] tubers gave 2.5 to 10 per cent of commercially extractable starch, according to the age of the plant, the lowest yield being obtained from tubers 2½ months old, and the highest from those 12 months old.

Tacca pinnatifida Forst., yielded 22.3 per cent of starch. This plant is rasped very easily and the starch is more easily obtained in a pure state from it than from any plant I have handled. Tacca starch sells for a higher price than the others, being called in the world's market Bermuda arrowroot.

Dioscorea sp. gave 11 per cent of commercially extractable starch with a total starch content of 14.3 per cent. This starch is remarkable for the small size of its granules.

The seeds of *Cycas circinalis* Linn., which are sometimes used as a source of "sago", yielded 31.2 per cent of starch.

The tubers of *Amorphophallus campanulatus* Blume are very large, but from them we were only able to obtain as the highest yield 4.5 per cent of starch. The presence of numerous spicules of calcium oxalate renders the preparation of an edible starch from this plant very difficult.

Raymond F. Bacon.

ILLUSTRATIONS.

PLATE I.

FIG. 1. Starch from *Manihot utilissima* Pohl.
2. Same in polarized light.
3. Starch from *Tacca pinnatifida* Forst.

PLATE II.

FIG. 4. Starch from *Tacca pinnatifida* Forst, in polarized light.
5. Starch from *Tacca pinnatifida* Forst.
6. Same in polarized light.

PLATE III.

FIG. 7. Starch from *Dioscorea* sp. In polarized light, this starch shows no change.)
8. Starch from *Cycas circinalis* Linn.
9. Same in polarized light.

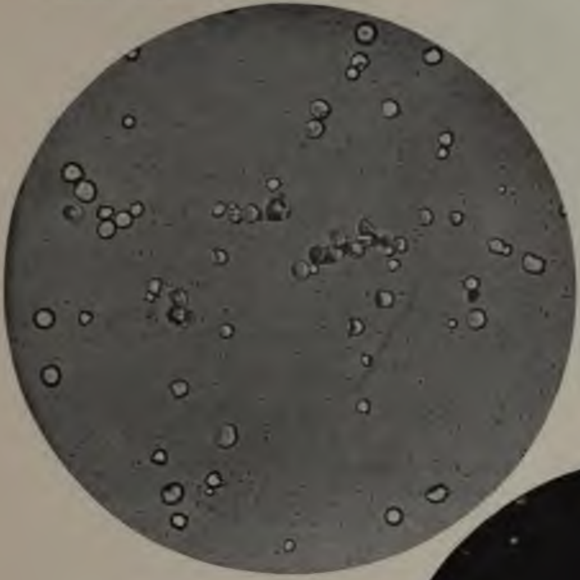

FIG. 1.

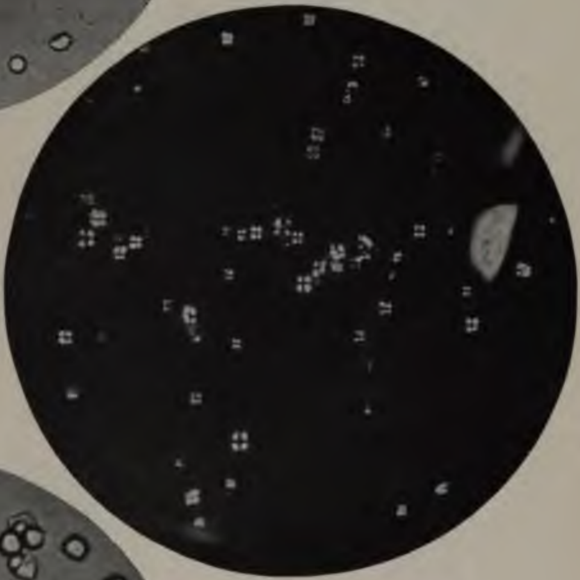

FIG. 2.

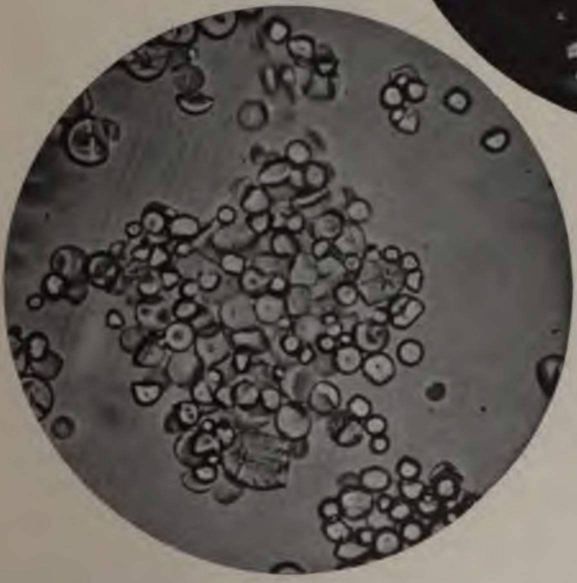

FIG. 3.

PLATE I.

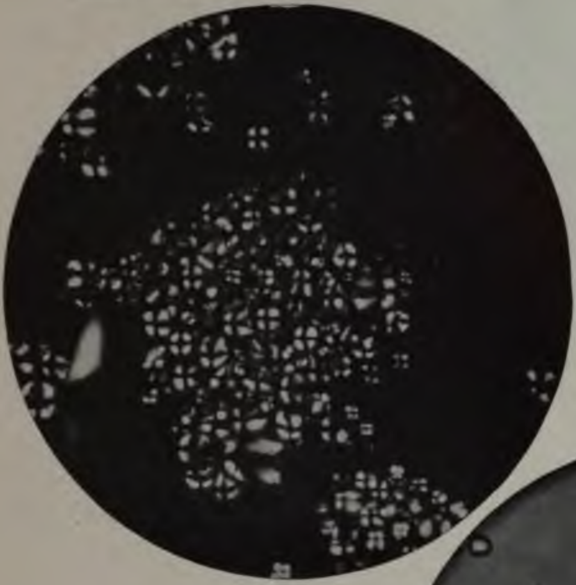

FIG. 4.

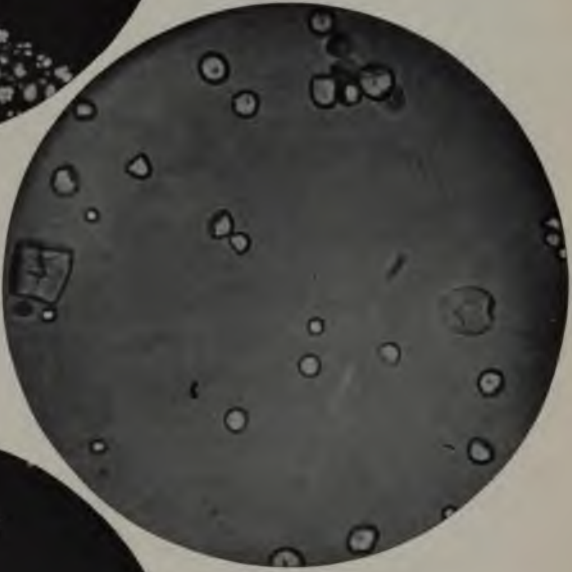

FIG. 5.

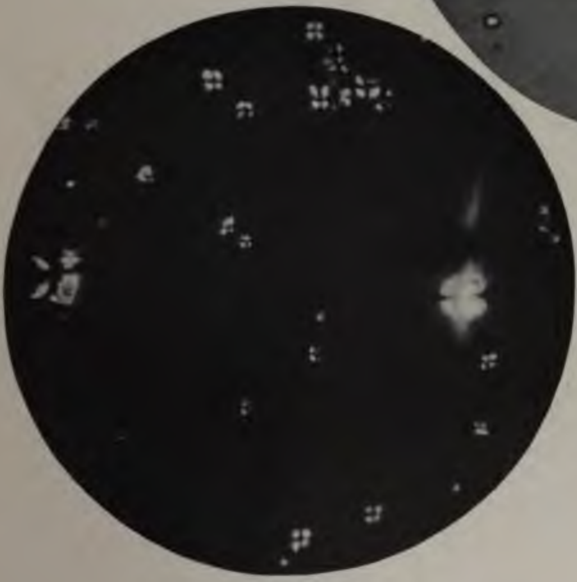

FIG. 6.

PLATE II.

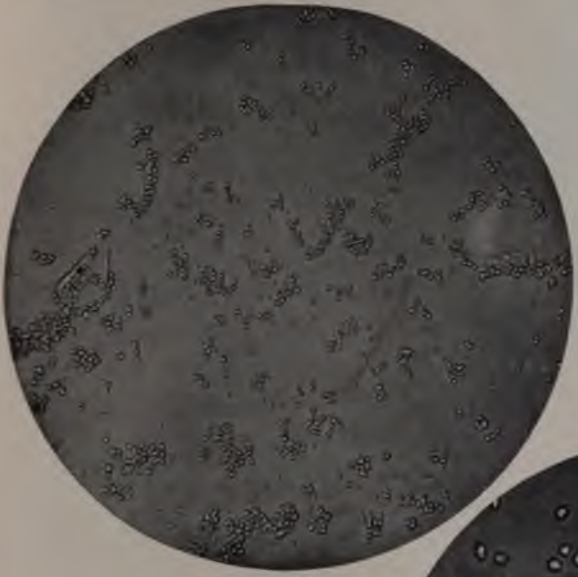

FIG. 7.

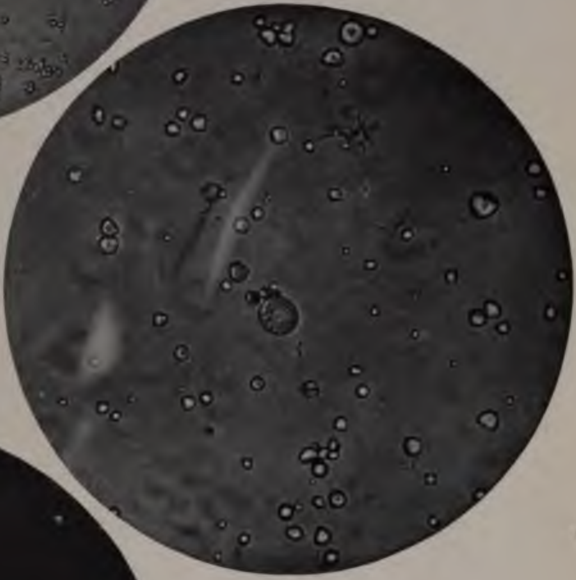

FIG. 8.

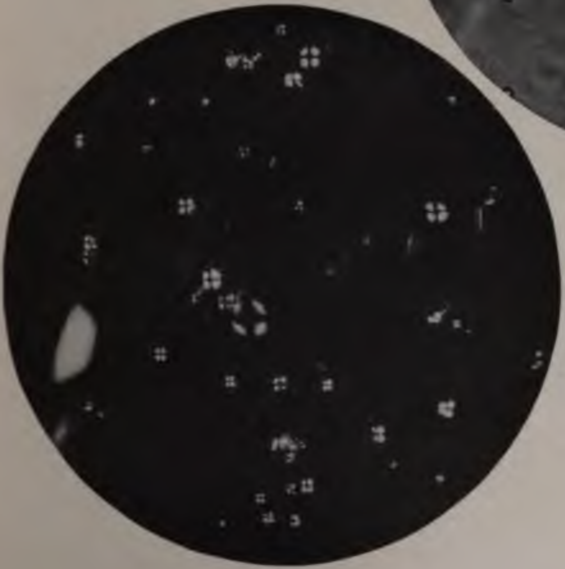

FIG. 9.

PLATE III.

THE ASCENT OF MOUNT PULOG.

The highest mountain in northern Benguet which has ever been ascended so far as is known, is Mount Pulog, recently climbed by Mr. Charles G. Benson and party of the Bureau of Lands. The notes which follow are taken from Mr. Benson's account of the trip.

Mount Pulog is in northeastern Benguet not far from the line between Nueva Vizcaya and Benguet. Kabayan, the settlement from which the start for the mountain was made, is a journey of a day and a half or two days from Baguio. From Kabayan the party went by the regular trail to the barrio of Lutab. One-half mile south of Lutab they turned off on the old Spanish horse trail which runs higher up on the hills than the trail at present used, and followed it to the Adat River. From this point they took a foot trail which runs up the cañon of the river at an average height of about 90 meters above it. After following this for one-half mile they traveled in an irrigation ditch for approximately two miles, then descended to the level of the river, crossing it at a point where two branches, one coming from the south of Mount Pulog and one from the north of that mountain, unite. After crossing the fork from west to east they climbed straight up over a very difficult foot trail to Ankiki, a little Igorot barrio of about four families, at an altitude of approximately 2,190 meters above sea level.

The trail from Ankiki to the top of Mount Pulog runs around the base of the main peak and over the tops of two subsidiary ones, after which it descends to the rancheria of Tinuk or Tinak, which is about 1,520 meters below the top of the mountain and lies to the south of the Asin Grande basin.

The top of Mount Pulog for a distance of about 240 meters below the summit, was found to be covered with very coarse-bladed grass a foot high. The height of the mountain, carefully estimated from barometric readings, is 2,890 meters. Ice five-eighths of an inch thick formed 60 meters below the summit during the night that Mr. Benson and his party spent there. A sufficient quantity of dead pine-wood for camp fires was obtained near the camp, 90 meters below the summit.

The time occupied in travel between the several points on this trip was approximately as follows: Kabayan to Lutab, ninety minutes; Lutab to the first barrio, one hour; the first barrio to the river bed, one and one-half hours; the river bed to Ankiki, four hours; Ankiki to the summit of Mount Pulog, two hours.

The people of the region passed through by this party are Benguet Igorots, but the following differences were noted between them and the main body of the people of the same tribe. The houses at Ankiki, while similar to those of others of this tribe, were rather better built, having sides of boards. The language spoken by the people of this barrio was hardly intelligible to an interpreter who belonged to the Ibaloi division of the Benguet Igorots. The people of Ankiki dress like the other Benguet Igorots. They are called by the latter *Kadasán* which is said to mean the people who live where the oak trees grow. Their only agricultural product is *camotes*. They keep hogs, dogs and a few chickens. They are great hunters and kill large numbers of deer and wild hogs.

The people of the barrio of Tinuk are called *Busols* by the Benguet people. This name is practically meaningless, as it is the common designation for people who seem to the Benguet Igorots more wild and uncivilized than themselves. The people of Tinuk raise rice but do not terrace the hillsides to any considerable extent.

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METHYL SALICYLATE I.—THE SEPARATION OF SALICYLIC ACID FROM METHYL SALICYLATE AND THE HYDROLYSIS OF THE ESTER.

By H. D. GIBBS.

(From the Chemical Laboratory, Bureau of Science, Manila, P. I.)

Since salicylic acid and the salicylates have been prohibited in foods,[1] it becomes necessary in many cases to separate salicylic acid and its metal salts from its esters.

The methyl ester, either the synthetic preparation or oil of gaultheria, or oil of betula, is often found to be a constituent of many non-alcoholic beverages, such as the so-called root beers, sarsaparillas, and soda-water flavors. The United States Pharmacopœia and the National Formulary [2] authorize its use as a flavoring agent, and it is therefore often found in emulsions, the most common of which is cod-liver oil and other pharmacopœial preparations.

Salicylic acid or its salts and its methyl ester may be, and often are, found together in the above preparations: *first*, through the incorporation of both in the original mixture; *second*, when methyl salicylate, or oil of gaultheria, alone is used the ester may contain varying amounts of free salicylic acid as an impurity; *third*, when a comparatively pure ester is employed, free salicylic acid may subsequently become a constituent of the compound through the hydrolysis of the ester.

Regarding the first of these sources, it is sufficient to note that preservatives of various kinds, borax and boric acid, benzoic and salicylic acids, have been found by the writer and other investigators in soda-water flavors, root beers, sarsaparillas and cod-liver oil emulsions, both when methyl salicylate was present and absent, and several manufacturers have verified the findings by submitting their formulas for some of these preparations. In many cases it is possible that a preservative, in addition to the methyl salicylate, is quite superfluous, the ester probably having antiseptic qualities [3] sufficient to render the employment of other sterilizing agents or processes unnecessary.

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[1] *U. S. Dept. Agric., Food Inspection Decision* 76 (1907).

[2] 3d ed. (1906), 46.

Concerning the second source of salicylic acid, namely, as an impurity in the methyl salicylate, an examination of all of the different samples available in this laboratory and in the city of Manila, eight in all, has revealed the presence of the free acid in every case. Two of these samples were represented to be genuine oil of gaultheria, and six were synthetic preparations. All were of European exportation and had been in stock in this city from a few days to over a year. The amounts of free salicylic acid varied from a trace in one laboratory sample to 0.025 per cent by weight in a genuine oil of wintergreen. These small amounts do not wholly account for the larger quantities of salicylic acid or its salts which have been found in a number of different preparations upon the local markets and entering the port of Manila.

The third source, namely, the hydrolysis of the ester, will be shown [4] to account, in many cases, for the presence of free salicylic acid in preparations in which comparatively pure methyl salicylate has been employed as an ingredient. With alkalies the rate of hydrolysis is very rapid; it is slower with acids, and even with distilled water the hydrolysis is measurable. The temperature is an important factor of the rate. It is therefore not surprising that the formation of salicylic acid from methyl salicylate in this way is quite appreciable in foods or drugs which have been shipped by vessels to this port. The temperature of the holds of the vessels often rises above 30° in the tropics. The voyage by fastest steamers from Europe or the United States occupies about one month and by sailing vessels a number of months, and during the entire voyage the rolling and pitching of the vessel produces a constant agitation of the contents of bottles, casks and other containers, maintaining, in all, favorable conditions for hydrolysis.

THE DETERMINATION OF SALICYLIC ACID IN METHYL SALICYLATE.

The free acid can be titrated directly. The indicators which have been found to be applicable are Congo red and erythrosin. Alfred J. Cohn [5] says, "Congo red may be used for estimating mineral acids in the presence of organic acids, as the latter do not affect it." This has been found to be an error, as salicylic acid can be accurately titrated, the end point being very sharp when either standard sodium hydroxide, carbonate or bicarbonate solutions are used, the carboxyl group only being affected. Walker and Wood[6] have used Congo red for titrating salicylic acid against baryta. Erythrosin has also been found to give fairly good results, although Congo red has been used almost entirely throughout this work.

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[3] It is hoped that this investigation will form a part of a later paper.

[4] While this phase of the question will be touched upon here, it will be further dealt with in a later paper.

[5] Indicators and Test Papers, J. Wiley & Sons, New York (1904), 56.

In titrating the free acid in methyl salicylate, from 5 to 20 cubic centimeters of the ester are shaken with an equal quantity of neutral, distilled water in a glass-stoppered flask, and standard alkali, $\frac{N}{50}$, added until the color indicating the end point remains permanent on shaking.

Standard solutions of sodium acid carbonate[7] are best used in this titration, for reasons explained further on, although sodium hydroxide solutions give accurate results. The titrations were carried out at the room temperature, which varied in this laboratory from 28° to 34°.

In order to show that the acidity of the samples was not due to acids other than salicylic, the following method was employed: Ten cubic centimeters of the ester or oil of gaultheria were extracted three times with 5 cubic centimeter portions of $\frac{N}{10}$ sodium acid carbonate. The acid carbonate solutions were united, extracted three times with chloroform to remove the ester which was in solution, made acid with sulphuric acid (1 to 3) and extracted three times with chloroform. The chloroform extracts were united, filtered into a weighed dish, and evaporated spontaneously in a vacuum desiccator. After weighing the residue, it was dissolved in hot water and the salicylic acid determined colorimetrically.[8]

TABLE I.—*Amounts of salicylic acid in natural and artificial oil of gaultheria.*

Sample.	Amount.	Salicylic acid—		
		By titrating.	By weighing.[9]	Colorimetrically.
	cc.	*Per cent.*		*Per cent.*
Oil of gaultheria (genuine)	10	0.025	5.5 mg. = 0.046 per cent	0.028
Synthetic	10	0.0113	3.9 mg. = 0.033 per cent	0.0113

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[6] *J. Chem. Soc.* (1898), **73**, 619.

[7] Standard solutions were made from Kahlbam's sodium acid carbonate, which was found to be very pure.

[8] Methods of Analysis, *Bull. U. S. Dept. Agric.* (1907), **107**, 180.

[9] The weights of the salicylic acid are evidently too great for the reason that drying was imperfect. Small quantities of the acid are so easily volatilized that it was considered preferable to err in the opposite direction and rely upon the colorimetric method for accuracy.

SEPARATION AND DETERMINATION OF SALICYLIC ACID AND METHYL SALICYLATE IN FOODS AND DRUGS.

The substance under investigation, containing salicylic acid and methyl salicylate, is made strongly alkaline to Congo red with an approximately normal solution of pure sodium acid carbonate, free from normal carbonate[10] and, if not homogeneous, the aqueous solution is separated and the process repeated with the residue until it is thoroughly extracted by the sodium acid carbonate solution. All of the salicylic acid has now passed into the acid carbonate solution in the form of sodium salicylate together with small amounts of methyl salicylate. This solution is extracted repeatedly, not less than three times, with small amounts of chloroform[11] until all traces of methyl salicylate have been removed. The sodium acid carbonate solution is now made acid with sulphuric acid (1 to 3) and extracted in the usual way to remove and determine the salicylic acid.[12]

This method has been successfully applied to emulsions of cod-liver oil which are usually very difficult to separate. The sodium acid carbonate layer, carrying the salicylic acid and small amounts of methyl salicylate, can be separated in a rapidly revolving centrifuge. With non-alcoholic beverages and soda-water flavors, the method is especially easy of manipulation. During the process of extraction, while the methyl salicylate is still in the solution with the salicylic acid salts, the temperature should not be unduly raised for the reason that the rate of hydrolysis of methyl salicylate is accelerated with increase in temperature. During the manipulation in this laboratory, where the temperature is always high, the solutions have been kept below 35°, which temperature has been found to be a fairly safe limit. Lower working temperatures are, of course, to be desired.

The ester, separated by chloroform extraction,[13] is saponified by heating in a flask with reflux condenser attached, on a steam bath, with a large excess of strong caustic alkali solution.

---

[10] Solutions of sodium acid carbonate lose carbon dioxide and therefore should be freshly prepared and kept in well-stoppered bottles. The loss of carbon dioxide, the increase of normal sodium carbonate, and consequent increase of sodium hydroxide in the solution is in most cases counterbalanced by the acidity of the substance under examination. When this substance is very acid it is best made alkaline by the addition of solid sodium acid carbonate in order to avoid a great increase in the bulk of the solution.

[11] Chloroform has been found to be better than ether for removing the methyl salicylate from this solution, for the reason that it is less miscible with the aqueous solution.

[12] Methods of Analysis, *Loc. cit.*

[13] In the case of oil emulsions and some other mixtures the ester is best separated, after the removal of the salicylic acid, by steam distillation from a sulphuric-acid solution. Since methyl salicylate is partially hydrolyzed on heating in a sulphuric-acid solution, it is necessary to carry on the distillation until all of the salicylic acid formed has passed over into the receiver.

After saponification is complete, half an hour usually being sufficient, the condenser is detached and the heating is continued until all of the chloroform is expelled. The solution is then diluted to a known volume and the salicylic acid determined in aliquot portions. The following quantitative experiments serve to show the manipulation and the accuracy of the method.

1.0256 grams methyl salicylate were dissolved in 50 cubic centimeters of chloroform and 10 cubic centimeter portions saponified with 10 cubic centimeters of a 25 per cent solution of caustic potash. After evaporation of the chloroform, the residue was diluted to 100 cubic centimeters and 2 cubic centimeter portions made acid with sulphuric acid (1 to 3) and extracted four times with small amounts of chloroform. The chloroform was evaporated in a vacuum desiccator, and the residue dissolved in 100 cubic centimeters hot water. The salicylic acid determined colorimetrically [14] in this solution gave 1.0640 grams methyl salicylate.

1.2277 grams treated as above gave 1.2667 grams.

0.1568 grams dissolved in 10 cubic centimeters of a 25 per cent solution of sodium hydroxide gave—

I.	II.
0.1499 gram.	0.1565 gram.

THE HYDROLYSIS OF METHYL SALICYLATE WITH SODIUM CARBONATE AND SODIUM HYDROXIDE.[15]

Solutions of sodium hydroxide, approximately $\frac{N}{5}$ and $\frac{N}{10}$, were made by dissolving clean, metallic sodium in distilled water from which the gases had been expelled by boiling. These were agitated in bottles with an excess of methyl salicylate and 10 cubic centimeter portions were removed and titrated at intervals.[16] The reactions were all carried on at 30°, with variations not exceeding ±1°. This is the prevailing temperature in this locality.

In the following tables, t is the time expressed in hours, v the volume of $\frac{N}{10}$ sulphuric acid used to neutralize 10 cubic centimeters of the reaction solution at time t, and x is the percentage of sodium hydroxide which has been used in the reaction.

---

[14] Color comparisons made with a wedge colorimeter.

[15] More extended investigation of the hydrolysis of methyl salicylate with acids, alkalies and water and the catalytic action of tropical sunlight is being carried on and will probably be presented in a later paper. The cases of sodium carbonate and hydroxide are here taken up merely to show the basis of the analytical methods.

[16] Ostwald-Luther: Physiko-Chemische Messungen, Leipzig (1902), 447.

TABLE II.—*Hydrolysis of methyl salicylate by sodium hydroxide.*

0.208 normal NaOH: T = 30° ± 0.5°.

t	*v*	*x*	*t*	*v*	*x*
0	20.30	0.00	6	2.30	88.67
1	14.70	27.58	7	1.70	91.62
2	9.60	52.70	8	1.25	93.84
3	6.65	67.24	24	0.30	98.51
4	4.60	77.34	31	0.20	99.01
5	3.30	83.74			

0.099 normal NaOH: T = 30° ± 0.5°.

11	0.30	96.96	18	0.15	98.48
15	.20	97.97	35	.10	99.00

$\frac{N}{5}$ sodium carbonate solutions were made from the pure salt and also from the carbonate formed by the ignition of sodium oxalate. A large excess of the ester was used in every case.

TABLE III.—*Hydrolysis of methyl salicylate with sodium carbonate.*

FIRST SERIES.

0.2 normal Na_2CO_3; T = 30° ± 1°.

t	*v*	*x*	*t*	*v*	*x*
0	20.0	0.0	32	14.20	29.0
1	19.4	3.0	48	13.2	34.0
2	19.1	4.5	56	12.9	35.5
3	18.7	6.5	72	12.35	38.25
5	18.1	9.5	80	12.1	39.5
7	17.65	11.75	125	11.46	42.7
8	17.3	13.5	144	11.28	43.6
24	14.9	25.5	152	11.24	43.8
28	14.4	28.0	168	11.2	44.0
31	14.25	28.75	194	11.1	44.5

SECOND SERIES.

8	17.5	12.5	64	12.65	36.75
9	17.1	14.5	80	12.15	39.25
10	17.0	15.0	88	11.97	40.15
11	16.8	16.0	133	11.40	43.0
13	16.5	17.5	152	11.2	44.0
14	16.2	19.0	160	11.22	43.9
16	15.9	20.5	176	11.18	44.1
32	14.25	28.75	202	11.02	44.9
33	14.1	29.5	225	11.0	45.0
36	13.9	30.5	254	10.95	45.25
39	13.75	31.25	323	10.7	46.5
40	13.7	31.50	489	10.45	47.75
56	12.9	35.5			

Table III.—*Hydrolysis of methyl salicylate with sodium carbonate*—Continued.

THIRD SERIES.

16	15.8	21.0	96	11.9	40.5
17	15.65	21.75	141	11.3	43.5
18	15.5	22.5	160	11.2	44.0
21	15.25	23.75	168	11.2	44.0
23	15.1	24.5	184	11.15	44.25
24	14.9	25.5	210	11.0	45.0
40	13.7	31.5	233	10.9	45.5
44	13.4	33.0	262	10.88	45.6
48	13.3	33.5	497	10.40	48.0
64	12.7	36.5	624	10.2	49.0
72	12.45	37.75	665	10.13	49.35
88	12.0	40.0	737	10.00	50.00

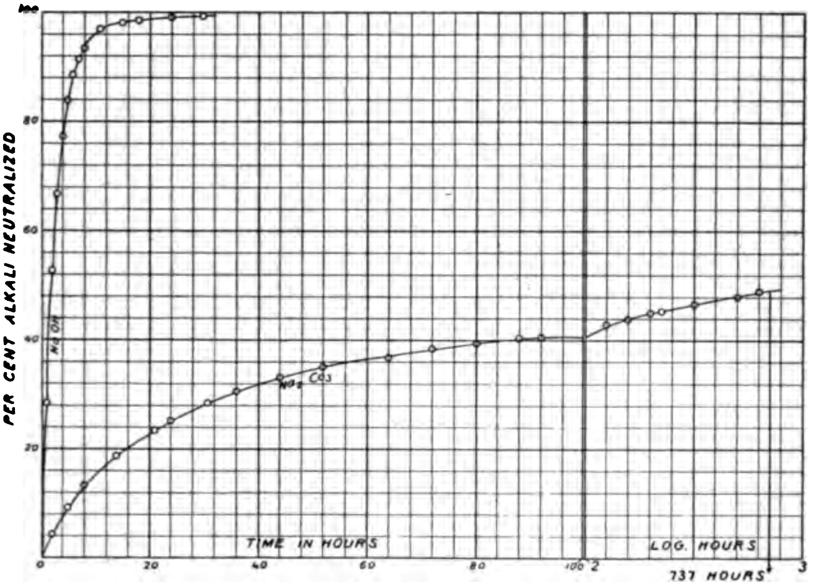

Fig. I.—Hydrolysis of Methyl Salicylate.

The rate of hydrolysis with sodium carbonate is a smooth curve, the break in the diagram being due to the change of scale.

The curves shown in fig. 1 are constructed from the above tables. It is to be noted that the hydrolysis of the ester with sodium hydroxide goes to completion; that is, to the point where all of the hydroxide has been used in the reaction, or at least it goes very nearly to completion in about twenty-four hours. With sodium carbonate, equilibrium, for all practical purposes, is reached in about one month, at the point where all of the normal carbonate has been converted into the acid carbonate according to the equation:[17]

$$C_6H_4 . OH . COOCH_3+Na_2CO_3=C_6H_4 . OH . COONa+CH_3OH+NaHCO_3$$

To prove that this is the end point of the reaction, or at least the point where the rate is exceedingly slow, the ester was shaken for days with pure $\frac{N}{10}$ sodium acid carbonate[18] solution in a number of sealed tubes. While a slight reaction was noted, it is believed that the substances were practically in equilibrium.[19] Any reaction taking place is not sufficiently rapid to affect the accuracy of the analytic methods previously described, which depend upon sodium acid carbonate for the removal of salicylic acid as sodium salicylate from the presence of the methyl ester, without saponification of the latter.

Cahours[20] says that concentrated solutions of alkalies react with methyl salicylate in the cold to produce the salts of the ester. Freer[21] has prepared sodium salicylic ethyl ester by the action of sodium upon the ester and by the action of sodium hydroxide upon the ester in etherial solution. He mentions the fact that the compound thus formed is easily hydrolized by moisture. The reactions with dilute solutions of sodium hydroxide and sodium carbonate, here described, are hydrolytic.[22] Analyses of the solutions at the end points of the reactions, prove that the products of the saponifications are present in the amounts indicated by the theory.

[17] The hydrolytic dissociation of sodium hydrogen carbonate according to the equation: $NaHCO_3+H_2O \rightleftharpoons NaOH+H_2CO_3$ necessitates a gaseous pressure of carbon dioxide and a continuous loss of the gas with formation of normal sodium carbonate in the solution. A discussion of this question may be more fully entered into a later paper. It is sufficient here to note that the effect due to this cause is very slight.

[18] The amount of the hydroxide in this solution is very small. McCoy, *Am. Chem. J.* (1903), **29**, 453, has calculated the concentration to be 2.9×10^{-6}.

[19] A more detailed discussion will be taken up in a later paper.

[20] *Ann. Chim. Phys.* (1844) (3) **10**, 327.

[21] *Am. Chem. J.* (1892), **14**, 411.

[22] Secondary reactions take place, to a small extent, not sufficient to affect the accuracy of the method. Some of these, probably due to light rays, are being studied.

TABLE IV.—*The analyses of the solutions described in Tables II and III at the end of the reactions.*

Solution.	Methyl alcohol.		Salicylic acid.	
	Theoretical.	Found.	Theoretical.	Found.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
0.203 normal NaOH	0.64	0.67	2.80	2.66
0.099 normal NaOH	0.32	....	1.37	1.41
0.2 normal Na_2CO_3	0.32	0.314	1.38	1.33

SUMMARY.

It is shown that methyl salicylate (synthetic), or oil of gaultheria, when used in foods and drugs, may give rise to the presence of salicylic acid, first, as an impurity in the ester; second, through its hydrolysis.

Methods for the separation and quantitative estimation of salicylic acid and methyl salicylate are described.

The rate of saponification of methyl salicylate in solutions of sodium hydroxide and carbonate are studied.

The work in some of its other phases is being continued.

NOTES ON THE SPROUTING COCONUT, ON COPRA, AND ON COCONUT OIL.

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(From the Chemical Laboratory, Bureau of Science, Manila, P. I.)

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I. EXPERIMENTS ON ENZYMES IN THE COCONUT.

The following experiments were made in an endeavor to discover if the coconut, like the castor bean and many other oil seeds, contains a fat-splitting enzyme capable of saponifying outside of the growing nut.

COCONUT FOOT.

Experiment I.—One hundred grams of the fresh foot in a sprouting coconut were ground with sand and water, and the expressed liquor was strained through cloth. One per cent of toluol was added and the whole allowed to stand on ice over night.

(*a*) Five cubic centimeters of water, 1 of *fresh liquor* and 0.25 of ethyl butyrate were kept in a water bath at 40° for fifteen minutes and then titrated; there were required 0.48 cubic centimeters of $\frac{N}{10}$ potassium hydroxide for neutralization. The mixture was allowed to stand until the next day, when it took 0.12 cubic centimeter more of the same solution of alkali.

(*b*) Five cubic centimeters of water, 1 of the *boiled liquor* and 0.25 of ethyl butyrate were placed under the same conditions as the above for fifteen minutes in a water bath; there were required for neutralization 0.45 cubic centimeters of $\frac{N}{10}$ potassium hydroxide and on the next day 0.11 cubic centimeter more.

(*c*) Five cubic centimeters of water, 1 of *fresh liquor*, 0.25 of ethyl butyrate, 1 drop of phenolphthaleïn, 0.28 cubic centimeter of $\frac{N}{10}$ potassium hydroxide and 0.1 of toluol were placed in a water bath for thirty minutes, then stood at room temperature until the next day, when 0.09 cubic centimeters of $\frac{N}{10}$ potassium hydroxide were required for neutralization.

(*d*) The conditions were the same as in (*c*) with the exception that boiled liquor was used. There were required 0.12 cubic centimeter $\frac{N}{10}$ potassium hydroxide for neutralization.

Conclusion.—No enzyme capable of hydrolizing ethyl butyrate is present in the press liquor from the coconut foot.

For comparison I give one experiment by Kastle and Loevenhart[1] working with a 10 per cent extract obtained from the pancreas of a pig.

One cubic centimeter extract, 4 of water, 0.26 of ethyl butyrate and 0.1 of toluol were kept at 40° for fifteen minutes and showed an increase in acidity corresponding to 1.63 cubic centimeter $\frac{N}{10}$ potassium hydroxide. A similar test with the boiled extract showed no increase in acidity whatsoever.

My *Experiment I* was continued as follows:

(*e*) Eight cubic centimeters of *fresh liquor*, 5 of coconut oil and 0.1 of toluol were allowed to stand one week. Eight cubic centimeters of $\frac{N}{10}$ potassium hydroxide were required for neutralization.

(*f*) Eight cubic centimeters of *boiled liquor*, 5 of coconut oil, and 0.1 of toluol were allowed to stand one week. 19.9 cubic centimeters $\frac{N}{10}$ potassium hydroxide were required for neutralization.

The boiled liquor showed a considerably greater acidity on standing than did the fresh, hence it is evident that no hydrolysis by enzymes had thus far been proved. The nut from which this foot was taken was perfectly sound and free from mold, but the inner surface of the meat next to the foot had begun to soften and had a greasy feel. A portion of this softened meat was dried and expressed, yielding an oil containing 3.3 per cent of free fatty acids, showing that hydrolysis to a marked extent had taken place in the growing nut.

COCONUT MEAT.

Experiment II.—The sprouting nut used for this series contained a foot which almost filled it. The meat remaining was ground in a sausage grinder and a cream-like emulsion pressed out.

(*a*) *The action with ethyl butyrate.*—The conditions were; 5 cubic centimeters of water, 0.25 of ethyl butyrate, 1 of toluol and 1 of cream, with the following result:

Conditions.	1¼ hours at 40° C.	Neutralized, let stand at room temperature 1 day.	Let stand 1 day more at room temperature.	Not neutralized, room temperature for 2 days.
Fresh cream	0.15 cc. $\frac{N}{10}$ KOH	0.12 cc. $\frac{N}{10}$ KOH	0.10 cc. $\frac{N}{10}$ KOH	0.92 cc. $\frac{N}{10}$ KOH
Boiled cream	0.35 cc. $\frac{N}{10}$ KOH	0.10 cc. $\frac{N}{10}$	0.10 cc. $\frac{N}{10}$ KOH	0.45 cc. $\frac{N}{10}$ KOH

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[1] *Amer. Chem. Journ.* (1900) 24, 491.

(*b*) The *cream alone* with 1 per cent of toluol as an antiseptic was allowed to stand four days in the incubator.

(1) Five cubic centimeters of boiled cream required 7 cubic centimeters of $\frac{N}{10}$ potassium hydroxide to neutralize.

(2) Five cubic centimeters of fresh cream required 12.8 cubic centimeters of $\frac{N}{10}$ potassium hydroxide to neutralize.

(*c*) After pressing out the cream used in (*a*) and (*b*), the residue was ground with sand and water and two fractions pressed out in the hydraulic press: A (up to 250 kilograms per square centimeter) and B 250 to 450 kilograms). These samples were kept under the same conditions as in (*b*) for four days and aliquot portions, each of 5 cubic centimeters, were titrated with $\frac{N}{10}$ potassium hydroxide. The following is the result:

A, boiled and fresh, and B, boiled and fresh, each took 0.05 cubic centimeter of $\frac{N}{10}$ potassium hydroxide to neutralize.

The cream from the first pressing (*a*) is therefore the only one showing any indication of enzyme activity.

(*d*) Five cubic centimeters of the cream from the first pressing (*a*), 5 of coconut oil and 2 of toluol were placed in an incubator for four days; there were required 12.4 cubic centimeters of $\frac{N}{10}$ potassium hydroxide for neutralization. A control made under the same conditions with boiled cream required 6.6 cubic centimeters.

The greater increase in acidity of the unboiled cream seemed at first to indicate enzyme action; but plate cultures made from the two tubes showed a considerable number of mold and bacterial colonies, these being more numerous in the unboiled than in the boiled cream. Therefore, it seems more reasonable to attribute the increase in acidity to the inefficiency of the antiseptic used, rather than to a specific enzyme action.

COCONUT MILK.

Experiment III.—The nut used had begun to sprout, its inner space being almost completely filled by the endosperm. About 50 cubic centimeters of milk were obtained and tested, the conditions being as follows: 5 cubic centimeters of water, 0.25 of ethyl butyrate, 1 of toluol and 1 of milk.

Conditions.	15 minutes at 40°.	12 hours at 35–40°.
Unboiled	0.28 cc. $\frac{N}{10}$ KOH	0.35 cc. $\frac{N}{10}$ KOH
Boiled	0.28 cc. $\frac{N}{10}$ KOH	0.38 cc. $\frac{N}{10}$ KOH

The results show no evidence of the presence of an enzyme in coconut milk.

MEAT AND MILK.

Experiment IV.—(*a*) The expressed cream from the meat of a nut just beginning to sprout was used, the conditions being as follows:

Five cubic centimeters of water, 0.25 of ethyl butyrate, 1 of toluol and 1 of cream.

Conditions.	At start.	Neutralized, and let stand 24 hours.	Not neutralized.		
			Room temperature 24 hours.	Incubator 24 hours.	
				a.	b.
		cc.	*cc.*	*cc.*	*cc.*
Unboiled	0.47 cc. $\frac{N}{10}$ KOH	0.18	1.82	1.24	2.00
Boiled	0.47 cc.	0.16	0.70	0.60	0.47

(*b*) Five cubic centimeters of water, 0.25 of ethyl butyrate, 1 of 1 to 1,000 formalin and 1 of cream were used. The unboiled mixture after twenty-four hours at room temperature took 0.55 cubic centimeter of $\frac{N}{10}$ potassium hydroxide and the boiled mixture 0.48 to neutralize.

Here again, although the unboiled cream increases in acidity fairly rapidly in the presence of toluol, the increase must be due chiefly to inefficient antisepsis, as it is almost entirely inhibited by formalin in a dilution of 1 to 7,000. Experiment has shown that formalin of this strength has practically no action on enzymes.

Experiment V.—The cream used in *Experiment IV* was treated with alcohol and ether, the precipitate washed with alcohol and finally with ether and then dried in a vacuum over sulphuric acid. One gram of this powder rubbed up with 20 cubic centimeters of water yielded a milky liquor which was tested for the presence of enzymes, the following being used:

Five cubic centimeters of water, 0.25 of ethyl butyrate, 1 of toluol and 1 of the liquor, the mixture being kept in the incubator at 35° to 40° for two days.

Both the boiled and unboiled liquor required 0.8 cubic centimeter of $\frac{N}{10}$ potassium hydroxide to neutralize.

It is evident that the precipitate obtained from coconut cream by the above method contains no fat-splitting enzymes.

COCONUT FOOT AND COCONUT OIL.

Experiment VI.—(*a*) One hundred grams of foot from two nuts with sprouts about 1 meter long were mixed in a mortar with 100 cubic centimeters of fresh coconut oil, 100 of water and 1 of chloral. The mixture was well ground for about one hour to prepare a good emulsion, it was then strained through cloth and 25 cubic centimeter portions were placed in small, stoppered Erlenmeyer flasks. The samples were then titrated at various intervals with $\frac{N}{10}$ potassium hydroxide, the result being given in cubic centimeters required to neutralize:

Time.	Cubic centimeters.
At once	13.5
1 day	12.0
2 days	12.2
7 days	13.8
8 days	18.5

Cultures made at the end of the last period showed the presence of molds and bacteria.

(*b*) One hundred grams of meat from the same nuts as were used in (*a*) were ground with 75 cubic centimeters of fresh coconut oil, 75 of water and 1 of chloral; 25 cubic centimeters of the strained emulsion required the following amounts of $\frac{N}{10}$ potassium hydroxide for neutralization:

Time.	Cubic centimeters.
At once	10.0
1 day	11.0
2 days	11.5
7 days	24.0
8 days	27.5

Cultures made at the end of eight days showed that the flasks were no longer sterile; they had all become slightly discolored at this time and in some cases possessed a bad odor. The slight increase in acidity in this comparatively long term must therefore be attributed to the actions of organisms, not to enzymes.

ATTEMPTS TO RENDER AN ENZYME ACTIVE.

Connstein, Hoyer and Wartenberg,[2] working with lipase from the castor bean, have shown that its rapidity of action is greatly increased by the addition of a small amount of acid. The following experiments were made to discover if this might not likewise render active any enzyme of the coconut which might be present.

COCONUT FOOT AND COCONUT OIL WITH HYDROCHLORIC ACID.

Experiment VII.—(*a*) Fifty grams of the foot from a nut with sprout about 1 meter long were shaved into fine pieces and ground in a mortar, first with 2 grams of chloral hydrate, then with 50 grams of fresh coconut oil and finally with 25 cubic centimeters of $\frac{N}{10}$ hydrochloric acid. Ten cubic centimeter portions of the resulting mixture were then placed in small, stoppered Erlenmeyer flasks and titrated from time to time with $\frac{N}{10}$ potassium hydroxide.

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[2] *Ber. d. Chem. Ges.* (1902), **35**, 3988.

Time.	Cubic centimeters.
At once	10.0
1 day	10.0
3 days	11.5
5 days	10.5
8 days	11.0
14 days	11.3
23 days	11.0

The result shows that practically no hydrolysis had taken place in twenty-three days. The flasks at the end of this time remained sterile.

COCONUT MEAT WITH HYDROCHLORIC ACID.

(*b*) One hundred grams of meat from a nut with a sprout about 75 centimeters long were thoroughly ground with 2 grams of chloral hydrate and 50 cubic centimeters of $\frac{N}{10}$ hydrochloric acid; 10-gram samples of the mixture were placed in small, stoppered Erlenmeyer flasks and titrated with $\frac{N}{10}$ potassium hydroxide after the addition of absolute alcohol and phenolphthaleïn. The result was as follows:

Time.	Cubic centimeters.
At once	8.5
2 days	10.0
4 days	9.1
13 days	11.1
19 days	11.2
22 days	11.5

The flasks were practically sterile at the end of twenty-two days. The slight apparent increase in acidity may almost be accounted for by experimental error, as in a non-homogeneous mixture such as this an exact titration is exceedingly difficult.

EXPRESSED LIQUOR FROM FOOT AND MEAT OF A SPROUTING NUT IN EMULSION WITH COCONUT OIL AND GUM ACACIA.

Experiment VIII.—One hundred grams of foot from a sprouting nut, 100 of meat from the same nut, 100 of sand and 100 cubic centimeters of a 2 per cent chloral hydrate solution were ground together in a mortar for two hours and the whole mass expressed; there resulted a muddy liquor consisting of water and partially emulsified oil. Fifty grams of coconut oil were rubbed up with 20 grams of gum acacia and 100 grams of this press liquor to form a permanent emulsion, 10 cubic centimeter samples of which were transferred to flasks and titrated with $\frac{N}{10}$ potassium hydroxide as in the previous experiments. The result was as follows:

Conditions.	At once.	2 days.	6 days.
	cc.	cc.	cc.
Press liquor + oil	7.0	6.7	9.2
Press liquor alone	9.7	9.5	12.3

No cultures were made from these flasks.

CREAM EXPRESSED FROM COCONUT MEAT, WITH ACETIC ACID.

Experiment IX.—(*a*) The entire meat from a nut with a sprout about 30 centimeters long was ground in a meat grinder and pressed in a hydraulic press up to 450 atmospheres, 50 cubic centimeters of the thick, cream-like press liquor, 25 cubic centimeters of a 1 per cent chloral hydrate and 2 per cent acetic acid solution were ground to an emulsion, weighed in separate portions of 10 grams each and titrated in alcoholic solution with $\frac{N}{10}$ potassium hydroxide.

Time.	Cubic centimeters.
At once	1.7
1 day	1.7
3 days	1.9
6 days	2.05
31 days	2.15

PRESS CAKE FROM MEAT, WITH COCONUT OIL AND ACETIC ACID.

(*b*) The press cake from (*a*) was dried over sulphuric acid at room temperature and ground to a fine powder; 2.5 grams of this powder with 22.7 of coconut oil and 10 of acid chloral solution were ground together for two hours in a mortar; 10-gram samples were taken for titration with $\frac{N}{10}$ potassium hydroxide with the following results:

Time.	Cubic centimeters.
At once	1.10
2 days	1.08
7 days	1.08

(*c*) A parallel experiment with the dried press cake from castor beans was made at the same time; 2.5 grams of the cake, 22.7 of coconut oil and 10 of acid chloral solution being ground together, and 10-gram portions were titrated with $\frac{N}{10}$ potassium hydroxide, with the result recorded below:

Time.	Cubic centimeters.
At once	2.7
1 day	12.4
2 days	15.0

EXTRACTED, DRIED AND PULVERIZED MEAT WITH COCONUT OIL AND ACETIC ACID.

Experiment X.—(*a*) The meat from a nut with a sprout about 30 centimeters long was cut into fine pieces and extracted with cold ether until practically all the oil was removed; the remainder was then dried in a current of air at room temperature, and finally in a vacuum over fused calcium chloride. When dry, it was ground to a fine powder and again dried over calcium chloride; 2.5 grams of this powder, 22.7 of oil and 10 of an acid chloral solution were ground together and 10-gram portions titrated with $\frac{N}{10}$ potassium hydroxide, with the following result:

Time.	Cubic centimeters.
At once	1.18
2 days	1.15
7 days	1.05

(*b*) The foot from same nut was extracted with cold ether, dried in a vacuum, and ground to a fine powder; 2.5 grams of this powder, 22.7 of oil and 10 cubic centimeters of acid-chloral solution were ground together and 10-gram portions used for titration with $\frac{N}{10}$ potassium hydroxide. There was practically no change, as is shown below:

Time.	Cubic centimeters.
At once	1.38
2 days	1.35
7 days	1.32

SUMMARY.

Experiments were first made with coconut meat, milk and the foot under varying conditions, to determine if they were capable of hydrolizing ethyl butyrate according to the methods employed by Kastle and Loevenhart, toluol being used as an antiseptic. In most cases no increase in acidity was noted. However, when hydrolysis did occur the tubes were found not to be sterile, the conclusion being that toluol is not a sufficiently strong antiseptic to prevent the growth of organisms in coconut extracts.

When formalin was used in a dilution of 1 to 7,000 the hydrolysis was entirely stopped. Formalin of this strength has almost no effect on enzyme action.

After this failure to hydrolize ethyl butyrate by means of extracts from the meat, milk and foot, attempts were made to emulsify and hydrolize pure coconut oil according to the method of Constein, Hoyer and Wartenberg, using different portions of the coconut, instead of castor beans. In no case were these attempts successful under sterile conditions, although parallel experiments carried on with castor bean press cake showed a decided hydrolysis.

In none of these experiments, which extended over a period of seven months, is the slightest proof given of the existence in the coconut of an enzyme capable of hydrolizing fat outside of the growing nut. The cause for the destruction of the fat in the growing nut must therefore be sought elsewhere. A discussion of the changes taking place in the sprouting nut is given in the following chapter.

II. CHANGES IN THE COMPOSITION OF THE COCONUT WHILE SPROUTING.

Four pairs of sprouting coconuts of different ages but approximately of the same size were selected for this work and their composition determined as follows.

TOTAL WEIGHTS.

After measuring the length of the sprout, the total weights of the whole nuts (including the shell but free from husk), the milk, foot, meat and sprout (with roots) were determined at once.

MEAT.

Three samples of 10 grams each were taken from each nut for analysis, viz:

Ten grams from that portion of the meat nearest the foot;

Ten grams from that portion of the meat farthest from the foot;

Ten grams as an average sample of the remainder which in Table I is calculated on the total.

Moisture.—The materials were dried for five hours at 100° C.

Oil.—The dried meat was ground to a fine pulp in a mortar and extracted in a Soxhlet cone with chloroform.

Sugar.—After removal of the oil the remainder was extracted with 50 cubic centimeters of water for three hours in the same apparatus as was used for oil extraction, the solution was then placed in a 100 cubic centimeter flask, clarified with basic lead acetate, the excess of lead removed with potassium oxalate, the whole diluted with water to 100 cubic centimeters, filtered, and after inversion, the sugar determined in 25 cubic centimeters of the filtrate by Fehling's gravimetric method.

Crude fiber.—This was determined in the residue from the extraction with water, according to the method of the *Association of Official Agricultural Chemists.*

FOOT.

Sugar.—Ten-gram samples were ground to a fine pulp and placed in a 100 cubic centimeter flask with about 50 cubic centimeters of water, they were then allowed to stand at room temperature with occasional shaking for three or four hours and diluted to the mark after the addition of basic lead acetate and potassium oxalate. Twenty-five cubic centimeters of the filtrate were inverted and the sugar determined by Fehling's gravimetric method.

Crude fiber.—Determined according to method of the *Association of Official Agricultural Chemists.*

MILK.

Sugar.—Fifty-gram samples were clarified, diluted to 100 cubic centimeters and 10 cubic centimeters taken for the Fehling determination (equivalent to 5-gram samples).

FREE FATTY ACID IN THE OIL FROM THE MEAT.

After determining the percentage of oil in the meat, the oil was titrated in alcoholic solution with $\frac{N}{10}$ potassium hydroxide, phenolphthaleïn being used as an indicator.

The results are given in the following table:

TABLE I.—*Changes taking place in the coconut during sprouting.*

Number.		1.		2.		3.		4.		5.		6.		7.		8.	
Length of sprout in centimeters		Not sprouted 0		Not sprouted 0		4		9		38		39		93		93	
Total weight in grams of nut free from husk (including sprout, roots and shell)		1038		1004		895		860		855		1002		875		760	
Total weight in grams of milk		374		307		275		200		177		100		0		0	
Total weight in grams of foot		19		29		42		49		90		178		228		213	
Total weight in grams of meat		457		421		382		403		327		400		152		148	
Weight of sprout and roots		0		0		Not weighed.		Not weighed.		42		70		244		139	
		Weight.	Per cent.	Weight.	Per cent.	Weight.	Per cent.	Weight.	Per cent.	Weight.	Per cent.	Weight.	Per cent.	Weight.	Per cent.	Weight.	Per cent.
Oil in meat	10 grams near foot	3.20	32.0	4.19	41.9	4.37	43.7	3.66	36.6	3.98	39.8	4.79	47.9	No meat near foot.			
	10 grams opposite foot	3.16	31.6	2.96	29.6	2.71	27.1	2.62	26.2	8.17	31.7	3.69	36.9	3.42	34.2	5.57	55.7
	Balance	157.	35.9	135.	33.7	116.	32.2	121.	31.7	115.	37.3	165	48.5	49.4	37.4	72.	56.4
Water in meat	10 grams near foot	5.40	54.0	4.24	42.4	4.18	41.8	4.92	49.2	4.53	45.3	3.70	37.0	No meat near foot.			
	10 grams opposite foot	5.27	52.7	5.25	52.5	5.73	57.3	5.88	58.8	5.24	52.4	4.65	46.5	5.12	51.2	2.62	26.2
	Balance	175.	48.8	195.	48.7	190.	52.5	202.	52.8	161	47.5	157	41.2	63.1	47.8	33.5	26.5
Sugar in meat	10 grams near foot	0.20	2.0	0.13	1.3	0.08	0.8	0.15	1.5	0.05	0.5	0.08	0.8	No meat near foot.			
	10 grams opposite foot	0.34	3.4	Determination lost.		0.43	4.3	0.42	4.2	0.36	3.6	0.36	3.6	0.15	1.5	0.08	0.8
	Balance	18.0	4.1	14.8	3.7	10.6	2.9	14.4	3.8	7.9	2.6	6.5	1.7	2.0	1.5	1.05	1.2
Crude fiber in meat.	10 grams near foot	0.22	2.2	0.31	3.1	0.17	1.7	0.19	1.9	0.25	2.5	0.24	2.4	No meat near foot.			
	10 grams opposite foot	0.21	2.1	0.26	2.6	0.17	1.7	0.16	1.6	0.17	1.7	0.17	1.7	0.17	1.7	0.19	1.9
	Balance	11.1	2.5	10.2	2.6	6.5	1.8	7.7	2.0	5.8	1.9	7.1	1.9	2.5	1.9	2.9	2.2
Crude fiber in foot		0.2	1.1	0.3	0.9	0.3	0.7	0.3	0.6	Determination lost.				6.1	2.7	3.8	1.8
Sugar in foot		1.7	8.1	2.6	9.1	2,7	6.4	3.1	6.4	4.0	4.8	9.1	5.1	22.1	9.7	27.7	13.0

DISCUSSION OF THE CHANGES TAKING PLACE.

Milk.—The total quantity of milk shows a marked diminution from 374 grams in an unsprouted nut to nothing when the sprouts have attained a height of 93 centimeters. A decided loss in the sugar content of the milk takes place at the same time, as this constituent falls from 2 per cent and 2.3 per cent in the milk from the unsprouted nuts to 0.3 per cent in the ones which have sprouts 38 centimeters in height.

Meat.—Here also a decided loss in total weight is evident, as it drops from 457 grams in nut number 1 to 148 grams in number 8. The loss seems to be due to a direct absorption by the foot, the process taking place at first only in that portion of the meat located near the *latter,* but increasing rapidly as the endosperm grows larger and comes in contact with the entire inner surface of the nut.

Oil in the meat.—The loss in total weight of oil is fairly proportional to the loss in total weight of meat, the percentage of oil in the meat remaining constant within the somewhat wide limits of individual variation. However, during the early stages of germination there is apparent a certain concentration of oil near the foot, with a corresponding loss in that portion of the meat farthest away.

Water in the meat.—As is the case with all the other parts of the nut, the meat gradually loses water by evaporation through the shell and sprout during the process of germination.

Sugar in the meat.—The percentage of sugar decreases from 4.1 per cent in the unsprouted nut (number 1) to 1.2 per cent in number 8. The loss is probably due to the absorption of sugar by the foot, as in all cases there is considerably less sugar in that portion of the nut in direct contact with the endosperm than there is in the parts farthest away from it.

Crude fiber in the meat.—No decided change in the proportion of this constituent can be observed. It is absorbed at practically the same rate as the rest of the meat.

FOOT.

Total weight.—The total weight increases from 19 grams in number 1 to 228 grams in number 7.

Sugar in the foot.—There is apparently a loss in the percentage of sugar (although not in its total weight) until the foot completely fills the nut, at which time there is a rapid gain. This phenomenon is probably due to the fact that the foot at first draws its sugar chiefly from the milk by which it is almost entirely surrounded. However, as it continues to grow, it soon exhausts the sugar in the milk, and only when it has completely filled the nut and come into intimate contact with the inner surface of the meat has it an opportunity to continue the process of sugar absorption and also one of sugar *creation*, possibly from the oil, or possibly from oil and crude fiber.

Crude fiber in the foot.—A slight increase in this constituent (from 1.1 per cent and 0.9 per cent in numbers 1 and 2, to 2 per cent and 1.8 per cent in numbers 7 and 8 respectively) will be noted.

If we consider the total weights of the constituents, oil, sugar, and fiber, the following changes may be remarked:

Oil.—A decrease from 163 grams in number 1 to 78 grams in number 8 is observed, or a total loss of 85 grams.

Sugar.—There appears to be a considerable loss in total weight of sugar during the intermediate period of germination, which is however again made up at the time the foot fills the entire nut. Increase in sugar takes place in the foot. Considering the first and last of the series, numbers 1 and 8, the following changes in sugar content have taken place:

Portion of the nut.	Loss.	Gain.
	Grams.	*Grams.*
Meat	17.0	
Milk	7.5	
Foot		26.0
Total	24.5	26.0

Crude fiber.—There is a slight loss in the total weight of fiber in foot and meat, which is more than made up by the increased weight of sprout and roots.

Free fatty acids and oil from the meat.—From the beginning, the oil from the meat nearest the foot is invariably richest in fatty acids, number 1, for instance, yielding 0.92 per cent in that portion, while the balance contains but 0.27 per cent. This difference becomes more marked as germination progresses; it is only when the foot has come in complete contract with all the meat that an increase in fatty acids throughout the whole nut is observed, indicating that oil, to be in a condition for absorption, must be hydrolized. This hydrolysis may take place as the result of an enzyme in the foot, or be caused by one in the meat, which is dormant until rendered active by some product of metabolism in the foot. However, as I have stated in the previous chapter, it was not possible to prove by an increase in free acid the presence of any fat splitting enzyme in the coconut. Such an enzyme may exist, but under such conditions that any large excess of free acid must be used up by the growing plant before the process can continue.

A summary of the changes to be detected by chemical analysis of the growing coconut is as follows:

Oil is lost by the meat; it is not taken up as such by any other portion of the nut, but is either burned to furnish energy for the growing plant or is split up, being transformed by progressive synthesis into sugar and finally to cellulose.

Sugar is lost by meat and milk, but a corresponding quantity is gained by the foot, the total amount in the nut remaining approximately the same.

A small amount of crude fiber is lost by the meat, but a much larger quantity is produced in the sprout and roots.

III. THE ACTION ON COPRA OF MICROÖRGANISMS IN PURE CULTURE.

It has been shown previously[3] that moist copra is readily attacked by microörganisms with consequent splitting up and destruction of the oil and it has also been proved that the action of such organisms is most pronounced when the copra has a water content of from 10 to 15 per cent. With this content of moisture the mold growth largely predominates over that of the bacteria. When much more water is present, and the bacteria are in excess of the molds, destruction of fat is greatly diminished. These observations led logically to the belief that hydrolysis of oil in copra was due to the action of molds alone, although the data available at the time the previous work was done did not exclude the possibility of symbiosis and interdependence in this fat-splitting process between molds and bacteria. Dr. Edwards, of the Biological Laboratory of this Bureau, undertook further work to settle this question definitely and in pursuing it separated as many different organisms as possible, some fifteen in all, from several samples of moldy copra and coconut meat, finally succeeding in isolating in pure cultures the majority of the growths present. As a culture medium he used sterilized coconut meat in most instances. The subsequent procedure was as follows:

Ten-gram samples of anhydrous copra were placed in large test tubes stoppered with cotton, and after the addition of 1.50 grams of water these were sterilized in an autoclave for half an hour. It was found by experiment that about 0.10 gram of water was taken up by the copra during sterilization, so that the samples thus prepared contained approximately 13.8 per cent of moisture, an amount which had been found previously to favor the growth of both molds and bacteria. The tubes were inoculated after sterilization with pure cultures of the organisms previously isolated, and allowed to stand at laboratory temperature (26° to 30°) for forty-one days. Cultures were then made from each tube. All tubes were dried to constant weight at 100° in order to determine the change in weight of the dry copra. The latter was next extracted with chloroform to determine oil and finally with hot water to take out the sugar, which was inverted and determined with Fehling's solution. The changes taking place in forty-one days are shown in the following table. Only those tubes which showed a good growth in this time and were proved by cultures to contain only one organism are noted.

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[3] *This Journal* (1906), 1, 123.

TABLE II.—*The decomposition of copra by bacteria and molds.*

	Weight of dry copra—			Oil.			Sugar.		Undetermined.	
	At start.	After 41 days.	Gain (+) or loss (−).	Weight.	Gain (+) or loss (−).	Free fatty acid.	Weight.	Gain (+) or loss (−).	Nitrogen, coloring matter, cellulose, etc.	Gain (+) or loss (−).
	Gm.	*Gm.*	*Gm.*	*Gm.*	*Gm.*	*P. ct.*	*Gm.*	*Gm.*	*Gm.*	*Gm.*
Control of sterile copra	10.00	9.99	−0.01	6.94	0.00	0.20	0.45	0.00	2.60	0.00
Bacterium CB2, fairly good growth	10.00	10.05	+0.05	7.13	+0.19	0.36	0.48	+0.03	2.34	−0.26
Bacterium CB1, fairly good growth, copra somewhat darkened, slight sour odor	10.00	9.36	−0.64	6.64	−0.30	0.21	0.08	0.37	2.64	+0.04
Bacterium W3+6, fairly good growth	10.00	9.98	−0.02	6.92	−0.02	0.20	0.50	+0.05	2.56	−0.04
Bacterium W5+6T, very slight growth	10.00	10.03	+0.03	6.91	−0.03	0.20	0.50	+0.05	2.62	+0.02
Mold W51, white, good growth, no odor	10.00	9.17	−0.83	6.06	−0.88	2.0	0.04	−0.41	3.07	+0.47
Mold W3, dark green, good growth	10.00	9.13	−0.87	6.14	−0.80	3.8	0.07	−0.38	2.82	+0.22
Mold $W_13_1l_1$, good growth in 6 days, ethereal odor, 9 days	10.00	8.84	−1.16	6.09	−0.85	24.7	0.02	−0.43	2.73	+0.13
Mold *Aspergillus catenatus*, rapid, heavy growth after 15 days	10.00	9.37	0.63	6.32	−0.62	8.3	0.05	−0.40	3.02	+0.42
Mold *Aspergillus flavus*, good growth in 7 days, ethereal odor after 15 days	10.00	9.13	−0.87	5.56	−1.38	12.0	0.06	−0.39	3.51	+0.91
Mold W3, 4, 5, good growth in 5 days, slight ethereal odor after 15 days	10.00	9.47	−0.53	6.24	−0.70	6.0	0.03	−0.42	3.20	+0.60

It was at first intended to identify each organism which was used experimentally, but this was found to be impracticable in this country where all literature is not available, except in the case of two molds, *Aspergillus catenatus* and *Aspergillus flavus*. It also seems probable that the majority of the other organism found in moldy copra in the Philippines are new and not yet described, and our mycological work is not yet far enough advanced to render descriptions of them possible. However, the main object of the experiments, namely the differentiation between mold and bacterial action on copra, has been accomplished. It is evident that in every tube containing an active mold culture, a decided loss in total weight (dry), ranging from 5 to 11 per cent of the original weight, occurs if the gain or loss in dry copra is first considered.

Only one bacterium, CB1, causes any appreciable loss in total weight. The molds destroy a certain percentage of the oil, and the greater proportion of the diminution in weight is due to this cause. These losses vary from 0.62 to 1.38 gram, which figures represent 8.9 to 19.9 per cent of the original weight of oil and they are in each case accompanied by hydrolysis of the oil to form fatty acids and glycerine, the final percentage of free acid varying from 2 in the case of "W51," to 24.7 per cent with "$W_1 3_1 1_1$."

There seems to be no relation between the percentage of free acid present and the total oil destroyed at the same time, the tubes containing the highest and the lowest percentage of free acid showing practically the same loss of oil. On the one hand, only one bacterium, "CB1," caused diminution of oil and this only to the extent of 0.3 gram, which is less than that brought about by the mold with the weakest action. Loss in oil is not accompanied by hydrolysis in this case. On the other hand, one bacterium, "CB2," appears even to have caused a slight gain in total oil. The sugar is almost completely destroyed by all molds and by bacterium "CB1." The *undetermined* matter shows a decided gain wherever mold action has taken place, this result being undoubtedly due to the weight of the mold itself.

Bacteria in all cases but one have produced no change in this constituent. "CB1" has caused a loss of 0.26 gram.

The results given above, when applied to the question of the diminution in value of commercial copra would render it certain that such copra, *if moldy,* has suffered a loss in total oil, of course not in all probability as great as I noticed in some cases (19.9 per cent), for my copras were placed under the most favorable conditions for the maximum of mold action, but nevertheless this change must amount to a sufficient quantity to be considered in the purchase of copra which has suffered from the action of molds.

Such materials undoubtedly can not give as good a yield of oil as others which have been carefully dried and preserved. However, another factor must also be considered. Poorly dried and preserved copras, if a sufficient quantity of water (above 15 per cent) is present, suffer from *bacterial* and not from *mold* action;[4] in which event no diminution of oil would be observed, but nevertheless bacteria so disintegrate and change the copra that a slimy, soft mass, difficult to work so as to procure pure oil reasonably free from acid, results. A bad odor also frequently accompanies such copras. In the Philippines a large amount of copra is dried by means of open fires in pits, the coconut meat is placed in bamboo gratings above, the fuel being the husks of the nuts. These conditions subject the materials more or less to the action of smoke, and it is not impossible that this procedure brings with it a slight antiseptic action which would tend to diminish the subsequent growth of organisms and work in favor of the final percentage of oil to be obtained in extraction. Nevertheless, the arguments are all in favor of preparing a clean, white, perfectly dried copra, which will not afford a medium for the growth of organisms unless the conditions of shipping which surround it are such as to allow of sufficient absorption of water after drying to facilitate mold growth.

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[4] This is clearly set forth in my paper on this subject in *This Journal* (1906), 1, 58.

SUMMARY.

Six different molds, any one of which is capable of hydrolyzing and destroying fat, have been isolated from among the many organisms found growing on rancid copra and coconut meat.

This fat destruction is part of the life process of the mold, and is independent of bacterial action, since it proceeds equally well in pure and in mixed cultures.

Copra which had been acted on by molds was found to have suffered an almost total loss of sugar.

The bacteria found on copra have very little effect on the quality or quantity of oil produced from it. A slight diminution in total weight of oil was found in only one case to be due to bacterial action. Practically their only effect is the production of a more or less disagreable "sour" odor and the disintegration of the meat.

It is good commercial practice to prepare only the best, white, perfectly dried copra.

IV. THE PRODUCTION OF FREE ACID IN COMMERCIAL COCONUT OIL ON LONG STANDING.

About 1 liter of crude coconut oil, freshly made from a rather poor quality of copra, was taken directly from a coconut-oil factory and allowed to stand in a large, wide-mouthed bottle for twenty-three days, until most of the turbid matter had settled out. During this time the free fatty acids had increased in percentage from 6.9 to 7.4,[5] or at the rate of about 8 per cent total increase per year. This rate of increase was fully double that which might be expected from a commercial oil of an initial acidity of 6.9 per cent, and it was thought possible that some abnormal influences were at work on this freshly prepared oil, which might or might not continue their effect on long standing; the logical idea being that the comparatively rapid splitting up of fat in copra by the action of molds was being continued in the oil, either by portions of the mold carried over through the factory filters, or by enzymes which were expressed and which would find their way into the final product.

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[5] This figure represents the clear portion of the oil. After shaking the bottle to obtain a representative sample together with sediment, etc., a figure of 7.6 per cent was obtained.

In order to determine if this supposition were correct, a number of 50-gram samples of the oil were subjected to different treatments, such as filtration to remove sediment and most of the water, the addition of antiseptic, sterilization by heat or by a combination of all three of the above processes. The oils were heated at a temperature of 100° in a water oven for two hours; ordinary quantitative filter paper was used for filtration. Two samples from each treatment were prepared, one being kept in a 100 cubic centimeter bottle half full, the other in a 50 cubic centimeter bottle filled to the neck. Unless otherwise stated, samples were sealed with paraffin and kept in the light. One sample, in the case of numbers 7 and 8, was kept in the light in 100 cubic centimeter Erlenmeyer flasks with sterilized cotton plugs, where air and light might be expected to play the leading part in any change produced; the other sample was kept in a wooden box covered with black paper.

The following table shows the change in acidity during a period of two years:

TABLE III.—*Change in acidity of coconut oil standing under different conditions for two years.*

No.	Description of oil.	Description of package and condition.	Free fatty acid at start of experiment.	Free fatty acid after 1 year.	Increase during the first year.	Free fatty acid after 2 years.	Increase during the second year.	Total increase in 2 years.
1	From original bottle unheated, unfiltered, no antiseptic.	a. Small bottle	7.6	11.2	3.6	11.6	0.4	4.0
		b. Large bottle	7.6	11.0	3.4	13.4	2.4	5.8
2	Unheated, *filtered*, no antiseptic	a. Small bottle	7.4	8.8	1.4	9.7	0.9	2.3
		b. Large bottle	7.4	8.8	1.4	11.2	2.4	3.8
3	Unheated, unfiltered, *+ 0.05 per cent chloral.*	a. Small bottle	7.6	9.6	2.0	10.9	1.3	3.3
		b. Large bottle	7.6	9.2	1.6	11.9	2.7	4.3
4	Unheated, *filtered*, *+ 0.05 per cent chloral.*	a. Small bottle	7.4	8.7	1.3	9.5	0.8	2.1
		b. Large bottle	7.4	8.7	1.3	10.2	1.5	2.8
5	*Heated*, unfiltered, *+ 0.05 per cent chloral.*	a. Small bottle	7.6	8.9	1.3	9.9	1.0	2.3
		b. Large bottle	7.6	9.0	1.4	11.2	2.2	3.6
6	*Heated*, *filtered*, *+ 0.05 per cent chloral.*	a. Small bottle	7.4	8.2	0.8	8.8	0.6	1.4
		b. Large bottle	7.4	8.9	1.5	10.4	1.5	3.0
7	*Heated*, unfiltered, *+ 0.05 per cent chloral*, kept in Ehrlenmeyer flask with cotton stopper.	a. In light	7.4	9.6	2.0	13.0	3.4	5.4
		b. In dark	7.4	9.6	2.0	*12.8	3.2	5.2
8	*Heated*, *filtered*, *+ 0.05 per cent chloral*, kept same as number 7.	a. In light	7.4	11.0	3.6	15.0	4.0	7.6
		b. In dark	7.4	11.6	4.2	*15.9	4.3	8.5

* Since no increase in acidity due to the action of light could be observed after one year, the samples previously kept in the dark were taken out and placed alongside the others serving simply as a check on the determinations.

It is necessary for the interpretation of these results to consider the many factors which may enter into the decomposition of a freshly prepared, commercial coconut oil.

First, we may have present fat-splitting molds, albuminoids, sugar and water, which cause the turbid appearance of commercial oils. It has been shown in a previous paper[6] that mold action on copra is the principal factor in determining the initial acidity of an oil, and that these same molds in the presence of sufficient nutritive matter may effect the rapid decomposition of even a pure oil. *Second*, soluble or insoluble enzymes produced by these molds may be the cause of the rise in free fatty acid. *Third*, surface oxidation by the air, possibly assisted by light, may take part in the decomposition. This surface oxidation is always accompanied by a pungent, disagreeable odor, and the formation of aldehydes and peroxides. *Fourth*, simple hydrolysis by heat and moisture may be a factor.

Considering first sample number 1 of this series, it is evident that 1-b, the sample in the large bottle, may be subject to any one or all of the foregoing factors causing increase of acidity, while 1-a, being in a practically full bottle, may be affected by any influence except that of oxidation by the air. Any marked increase in acidity, then, of 1-b over 1-a would be due to surface oxidation. By reference to the table we find that during the first year there has been practically no difference in the rate of increase of acidity between 1-a and 1-b, which show respectively a gain of 3.6 and 3.4 per cent. The second year, however, indicates a decidedly different condition. While 1-a has only gained 0.4 per cent free acid, 1-b has increased 2.4 per cent, leaving a difference of 2 per cent which can only be due, aside from experimental error and an individual variation in the samples, that should at most amount to no more than a few tenths of a per cent, to surface oxidation by the air. The question naturally arises, why should a period of two years be required for this difference to show itself? This can be accounted for by two theories: *First*, the presence of molds and of nutritive bodies such as sugar and albumen, which would be in the oil in larger quantity in the first year than in the second, is not favorable to the formation of peroxides of the fatty acids, a fact I have previously noted in testing pure and commercial oils for peroxides and aldehydes;[7] *second*, it is possible that this inhibiting effect may be mutual, so that oxidation once started would tend to kill off or check mold or enzyme activity in 1-b sooner than this activity would naturally cease through lack of nutriment in 1-a. In either case, the result would be the same and the combined effect of the two processes, each ending ultimately in the production of free acid, might be less than either of them working singly. The probabilities are that oxidation does not set in until most of the nutritive substances present in the oil are used up, thus it would be natural to expect that for a certain period of time no difference in the rate of acidification of an oil, due to the size of the container, would be observed.

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[6] *This Journal* (1906), **1**, 139.

[7] *Loc. cit.*, 139.

Sample number 3 was filtered, removing molds, albuminous matter and any enzymes insoluble in oil, together with most of the water. During the first year an increase in acidity of 1.4 per cent was noted. The difference between this figure and 3.6 per cent, the increase of 1-a for a corresponding time, gives 2.2 per cent which may be attributed to molds and insoluble enzymes. Practically no difference, due to size of bottle, is observed in number 2 as well as in nearly all the other samples, during the first year, although it is quite marked at the end of the second year. Number 3 differs from number 1 only in containing a small amount of antiseptic. It shows 1.6 per cent less increase during the first year than number 1. This can be due only to inhibition of molds. During the second year 3-a has increased 0.9 per cent more than 1-a, a fact for which I can find no explanation, except that during the second year some surface oxidation may have taken place, even in the small bottles. Five cubic centimeters of oil had been removed for titration at the end of the first year, thus leaving a small air space. This being the case, somewhat wider variation in acidity might be expected. The figure of 0.4 increase for the second year in the case of number 1-a seems exceptionally low, compared with the other samples during this period. 3-a has increased only a trifle more in acidity as compared with 2-a, thus proving that the addition of antiseptic has about the same effect as filtration and that most of the difference in behavior of a filtered and an unfiltered oil is due to the removal of molds and insoluble enzymes. Number 4 was filtered and treated with antiseptic with results which practically correspond with those of 2 and 3. Filtration appears to be slightly more efficient than adding antiseptic. It is quite possible that chloral in the strength used does not have an immediately fatal effect on fat splitting molds, although it certainly inhibits their action to a very marked extent.

Numbers 5 and 6 have both been heated at 100° and treated with antiseptic, thus eliminating mold and enzyme action, and in the case of full bottles leaving only the factor of hydrolysis to be considered. As would naturally be expected, the filtered sample, 6-a, has increased in total acidity considerably less than 5-a, from which the water was not removed. Only number 6 of the whole series shows practically the same difference at the end of each year between the full and the half full bottles. The slight, but regular, increase in acidity of 6-a is probably due to the hydrolytic action of a trace of water not removed by filtration, combined with the free fatty acids already present. Some slight oxidation also may have taken place, as the bottle was not absolutely free from air.

Numbers 7 and 8, sterilized and kept under antiseptic conditions in Erlenmeyer flasks, with a large oil surface exposed and free access of air through the cotton plugs, practically doubled their percentage of free acid in two years. The filtered samples of number 8 show considerably more increase than the unfiltered oils numbered 7, a fact which tends to confirm my belief that as a general rule the freer an oil is from moisture and impurities the more quickly is it subject to oxidation when exposed to the air. The samples kept in the light have not increased in acidity any more than those kept in the dark, in fact, 8-b at the end of one year contains 0.6 per cent more free acid than 8-a.

In view of this latter work, indicating the considerable variation in acid content of the same oil which may be brought about by different sized containers with consequently varying amounts of oil exposed to the air, it was decided to bring to a close the series of oils described in a previous paper[8] and which were set aside to determine the amount of free acid which might be produced on standing, since after the first year, most of the further increase in acidity would be dependent to a very large extent upon the amount of oil surface exposed to air in the bottles. No attempt was made at the time when these samples were prepared to exclude oxidation by keeping them in filled bottles, and with few exceptions no record was kept of the quantity of oil in a bottle, so that wide variations in acidity after the first year were to be expected. For convenience, a description of the oils as first made is reprinted here, together with a table giving their increase in free fatty acid from the time of their preparation up to the present date.

DESCRIPTION OF OILS USED AND DESCRIBED IN TABLE IV.

(A) Expressed oil from vacuum-dried copra. Has been heated for two hours at 100° and filtered twice through paper. A light-colored, clear oil with the characteristic coconut taste and odor.

(B) An oil similar in every respect to "A" except that it was prepared from copra dried at 80° to 90°, without vacuum.

(1) Fresh coconut meat grated and dried at 80° to 90° on August 16, 1904; was allowed to stand in a covered specimen jar until March 11, 1905. At that time it was still of a pleasant odor and taste, although both odor and taste were not quite as good as when the specimen was freshly prepared. No mold

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[8] *Ibid.*, 118.

growth was present. A sample of oil was expressed from a portion of this copra by using a hydraulic press with a final pressure of 450 kilograms per square centimeter. This oil, after filtration, was of a light yellow color and it was of a pleasant, although slightly burnt, odor and taste.

(2) Oil number 1 was heated at 100° for three hours, while at the same time a current of air in a partial vacuum was passed through it. This process leaves the color and free acid unchanged, but removes almost all of the burnt odor, leaving a bland, almost tasteless, oil.

(3) An oil from the same copra as numbers 1 and 2, but prepared by extraction with petroleum ether. Afterwards it was treated in the same manner as number 2. It differs from numbers 1 and 2 in being practically colorless.

(4) Commercial coconut oil treated with alcohol and animal charcoal and then filtered; the alcohol was afterwards distilled and recovered. This oil was rather unpleasant to the taste, but it had no odor.

(5) Commercial coconut oil treated with live steam; this removes the odor, but the unpleasant taste remains.

(6) Fresh meat, ground and dried in vacuum at 70° to 80°. The oil was expressed and once filtered; it possessed a very pleasant, coconut-like odor and taste. It still contained a considerable amount of sediment.

(7) Coconuts cut in halves and dried in vacuum at 75° to 85°. The oil expressed and filtered twice. It had a very pleasant odor and taste.

(8) The same oil as number 7, heated at 100° for one and one-half hours and filtered hot.

(9) The same as number 7, heated at 100° for one and one-half hours, while at the same time a current of air was passed through the oil under partial vacuum. Filtered hot and bottled.

(10) Fresh coconut meat, ground and pressed in a hand press to remove most of the milk. Afterwards this meat was dried completely by spreading it in the sun for about five hours. The oil expressed from this copra was almost water white and without taste and odor.

(11) Coconuts split in halves and dried in the sun for five days. Ground and expressed. Yielded a cloudy, slight colored oil, very hard to filter, with a peculiar, but not unpleasant, taste and odor. This sample was strained through cloth but not filtered.

(12) Same as No. 11, strained and filtered slowly through paper.

(13) Same as number 11, heated at 100° for two hours and filtered through paper.

(14) Fresh nuts, split in halves and allowed to stand during one week in the air at room temperature (about 30°). A vigorous mold growth and an unpleasant odor developed. This moldy meat was dried in a vacuum and the oil was expressed. This was highly colored and was rather unpleasant to taste and smell.

(15) Commercial coconut oil shaken with 2 per cent of solid calcium oxide (burned lime), heated to 100° and filtered. The filtrate was treated with animal charcoal and again filtered; there resulted a colorless oil which was very free from an unpleasant odor or taste.

(16) The same copra as that used for number 1; was allowed to stand one month longer in an open jar, then expressed.

(17) Oil expressed from vacuum-dried copra which had stood for one month exposed to the air; the oil was heated to 100° and filtered.

(18) Expressed from sun-dried copra and treated in the same manner as number 17. Both of these samples were of as pleasant a taste as oils from fresh copra.

(19) Vacuum-dried copra which had stood in a closed desiccator over water for one month, and which had accumulated a very decided growth of mold. It was dried for one hour and expressed. The oil had a considerable color and was slightly unpleasant as to taste and odor. Heated to 100° and filtered.

(20) Sun-dried copra treated in the same way as number 19. Yielded an oil somewhat darker in color but otherwise much the same as number 19. Filtered without heat.

(21) Same as number 20, heated to 100° before filtering.

(22) The same copra as that used for samples 1 and 16 was allowed to stand for three weeks over water and for one week in air, and then dried and pressed. A vigorous mold growth appeared in the copra and a peculiar ethereal odor was apparent. The oil itself was of a light-yellow color, with a pungent, rather unpleasant, odor and an extremely disagreeable taste.

(23) Expressed from commercial copra, first quality, sun dried, Tacloban, Leyte. The unfiltered oil is dark colored and cloudy, depositing a black sediment.

(24) Same as number 23, filtered. Almost colorless.

(25) Expressed from commercial copra, grill dried, Laguna (second quality). Not filtered.

(26) Same as number 25, filtered. Light yellow in color.

(27) Expressed from commercial copra, grill dried, Romblon (considered second quality). The filtered oil is light yellow color.

(28) Expressed from commercial copra, first quality, sun dried, Iloilo. The filtered oil is light yellow in color.

(29) "Langis" coconut oil, prepared by the customary native process of grating the fresh meat, exhausting it repeatedly with water, and boiling down the emulsion thus obtained until it is nearly dry. The oil is then poured off from the brown coagulum which sinks to the bottom of the vessel. A freshly prepared oil, isolated in this manner, is very light in color and it possesses a decidedly pleasant coconut odor and taste. Before filtration it is more or less turbid, owing to the presence of a small amount of water and of albuminoids.

(30) Same as number 29, filtered. The oil is water white.

(31) Best grade commercial coconut oil, probably made from fresh meat. It is light colored, but very turbid and contains considerable water and suspended matter.

(32) Commercial coconut oil, probably made from copra. Very clear but highly colored.

(33) Commercial coconut oil, Manila. Probably made from fresh meat. It contained considerable suspended matter and water.

(34) Commercial coconut oil, Cebu. A highly colored "rancid" oil. Considerable sediment in the bottom of the bottle.

(35) Commercial coconut oil, Tayabas. A highly colored rancid oil made from copra. It is only a few months old.

Table IV.—*Percentage free fatty acid (as oleic).*

No.	At start.	Two months.	Four months.	Six months.	One year.[a]	Three years.
A	0.06	0.06	0.09	0.60	2.6	9.6
B	0.06	0.06	0.08	[b]0.48	[c]2.3 [d]0.14	8.9 0.37
1	1.2	1.3	1.5	1.9	3.1	9.4
2	1.2	1.5	1.5	1.7	2.1	3.7
3	1.4	1.6	2.1	2.6	3.9	----------
4	5.3	----------	5.9	6.1	6.8	9.0
5	5.5	----------	----------	7.6	10.1	28.2
6	0.10	0.16	0.19	0.30	0.53	1.9
7	0.16	0.18	0.19	0.27	0.39	1.0
8	0.16	0.14	0.19	0.30	0.40	0.93
9	0.16	0.16	0.18	0.25	0.35	0.93
10	0.16	0.16	0.21	0.28	0.54	1.5
11	0.13	0.18	0.25	0.28	0.43	3.5
12	0.18	0.10	0.10	0.14	0.28	1.0
13	0.13	0.09	0.09	0.15	0.28	1.1
14	3.5	3.7	4.0	4.3	4.7	5.7
15	0.32	----------	0.88	----------	3.3	----------
16	1.6	1.7	2.0	----------	4.4	----------
17	0.09	0.09	0.14	0.16	0.25	0.81
18	0.16	0.18	0.25	0.27	0.44	0.82
19	1.18	1.14	1.34	1.58	2.0	3.5
20	0.69	0.69	0.74	0.85	1.1	2.7
21	0.69	0.69	0.74	0.82	1.1	2.0
22	23.3	----------	----------	----------	30.0	----------
23	1.4	1.6	1.8	2.0	2.5	3.9
24	1.4	1.5	1.7	1.8	2.5	6.0
25	2.6	3.4	3.6	3.9	4.8	----------
26	2.6	2.6	3.1	3.5	4.5	----------
27	2.1	2.4	2.5	2.8	3.1	4.2
28	3.0	3.5	4.0	4.7	6.1	11.4
29	0.08	0.38	0.60	0.69	1.4	3.9
30	0.08	0.13	0.16	0.19	0.80	----------
31	2.0	2.9	----------	----------	7.5	----------
32	6.8	7.5	7.9	8.1	9.2	16.1
33	5.5	----------	6.9	7.2	8.2	16.5
34	8.7	----------	10.2	11.0	13.8	----------
35	5.0	5.5	----------	----------	8.2	----------

[a] The greater part of the titrations at this period were made by Mr. L. A. Salinger of this Bureau who kindly continued the series during my absence from the Bureau.

[b] This oil was kept in a large bottle. A sample in a small bottle showed an acidity of only 0.09 at this time.

[c] Large bottle.

[d] Small bottle.

The most apparent fact which is noted on examining these tables is the proportionately large increase in free acid after the first year.

In some samples this change is so great and so unexpected as to appear at first glance inexplicable, but in such cases I have nearly always been able to detect some abnormality in the conditions under which the sample had been kept. For instance, numbers 1 and 2, samples of identically the same oil, the only difference between which lay in the fact that number 2 had been treated for three hours with a current of dry air to deodorize it, increased in free acid in practically the same ratio during the first six months; at the end of a year number 1 contains only 1 per cent more acid than number 2, but after three years shows 9.4 per cent as against 3.7 per cent in number 2. On examining the bottles in which these samples were kept I noticed that number 1, of which a considerable quantity had been prepared at the start, was still in the original 250 cubic centimeter bottle in which it had first been placed. About half of this oil had afterwards been taken out for the preparation of number 2, and filled into a 100 cubic centimeter bottle. This difference in the size of bottle, then, with a corresponding different surface exposed to oxidation, must account for the 5.7 per cent excess of free acid of number 1 over number 2.

A still more striking example of the influence or surface oxidation is afforded by sample B. This was an exceptionally pure oil, sterile and freed as far as possible from impurities by repeated filtration. One portion of about 25 cubic centimeters was transferred to a small bottle nearly, but not quite, filled, shortly after preparation, while in the original 500 cubic centimeter bottle there remained at the end of three years about 20 cubic centimeters of oil. The latter sample has increased in acidity 8.8 per cent in three years, while the former, from which air was nearly completely excluded has gained only 0.31 per cent free acid in the same time. Sample number 5, a commercial oil which changed from 5.5 per cent free acid to 28.2 per cent, had originally been treated with live steam to remove its unpleasant odor, and decanted into a bottle without filtering out all the water of condensation from the steam. When the final titration was made there remained between 5 and 10 cubic centimeters of oil, together with considerable water, so that hydrolysis by water undoubtedly had much to do with the large amount of free acid developed.

It will be noted that oxidation once started proceeds more rapidly in oil already having a large free acid content than it does in those comparatively low in acidity (compare numbers 6 to 13 and 17 to 21 with the commercial oils from number 23 on). Exceptions to this rule are, as above stated, due to abnormal conditions of storage.

The behavior of these oils during the period prior to the appearance of oxidation has been discussed in a previous paper and no new data have been brought out by longer storage which do not tend to confirm the conclusions drawn at that time.

CONCLUSIONS.

The deterioration of a freshly prepared commercial coconut oil is produced by at least three entirely independent processes and may be divided into two distinct periods of time.

The first, rapid splitting up of the fat, beginning immediately after its expression from copra and continuing for several months up to a year or more according to the nutrive matter present, is occasioned by molds which are either pressed out with the oil together with sufficient sugars and albuminoids for their growth, or, in the case of hot pressed oils, enter the freshly prepared oil from the air. This action continues as long as sufficient nutritive material for mold growth remains in the oil. It may be completely checked by filtration, preferable after heating to 100° C. more thoroughly to coagulate albuminoids and to destroy any enzymes already secreted by the molds.

Toward the end of this first period, oxidation by the air sets in and may continue indefinitely. The rate of this process depends upon the amount of surface exposed to the air, compared with the total volume of oil, and may in extreme cases cause an exceedingly rapid deterioration. It may be entirely prevented by storing the oil in completely filled receptacles, impervious to air.

Along with the two above-mentioned processes, a slight hydrolysis due to heat, moisture and free acids already present is constantly taking place. It may be reduced considerably by filtration, which removes most of the water, together with the organic impurities.

There is reason to believe that some hydrolysis is brought about by enzymes produced by the molds, as unheated oils which have been filtered and rendered antiseptic increase in acidity somewhat more rapidly than do heated ones under the same conditions. However, this distinction is not so apparent after the first year.

Light has apparently no effect on the oxidation by air of coconut oil.

PORTLAND CEMENT TESTING.

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INTRODUCTION.

This paper is devoted to a discussion of modern cement specifications and we have endeavored to point out many reasons why they do not exclude the personal error that is experienced by all testers working under them. Simple methods and precautions necessary to reduce this variation have been suggested. Throughout the discussion, the effects of the requirements of cement specifications, the difference possible in manipulation and the consequent variations in the results obtained have been illustrated. Certain powerful climatic influences that tropical conditions may exert upon cement are also discussed, and the last chapter suggests the characteristics which a cement should have to give the greatest efficiency under tropical influences.

SPECIFICATIONS.

The "value of standard specifications to the engineer, the consumer, and the country at large is as great as their value to the manufacturer. A standard specification, provided it is both equitable and safe, cheapens the product, insures quicker deliveries and acts as a powerful regulator to the industries affected. * * * *The danger of a fixed standard of any kind lies in its becoming unprogressive and following behind the demands of the time.*"[1]

The last sentence should be especially emphasized. All official cement testing in the Philippines at present is done under the United States Army Engineer Specifications of 1902. No change has been made in these specifications in the last six years despite the great amount of work which has been done upon the physical and chemical properties of Portland cement in recent times, and, in the light of experience, it has been found that these specifications could certainly be improved. This unprogressive tendency is, perhaps, due to the inertia inherent in all committee work. Each individual member has fixed ideas on certain questions, or on the results of certain personal experiences. As one writer puts it: "We are all disposed to argue somewhat on the basis of our prejudices or to refute others because of the prejudices which we associate with them. * * * Therefore it is difficult for us to arrive at conclusions purely by the light of reason, and to deal with every syllogism from its premises to its conclusions."

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[1] Editorial: *Eng. News* (1904), **51**, 612. (Italics supplied.)

However, the American Society of Civil Engineers and the American Society for Testing Materials are constantly working to improve their cement specifications and these specifications will soon be adopted by the Government of the Philippine Islands for all civil and municipal work. They have accomplished much towards establishing a more practical, impartial and comprehensive system of testing. Yet "notwithstanding that so much has been done towards unification of methods, it may never be possible to determine accurately the value of one cement as compared with another tested in a different laboratory".[2] "Experience since the report of the committee was made has shown that the difficulties in the way of uniformity in such tests are much greater then was then imagined. The variation in the results of tensile strength between the work of different experienced operators working by the same method and upon the same material are frequently very large and often make all the difference between rejected and accepted cement. Differences in tensile strength with neat cement of 40 to 60 per cent are not uncommon, while for sand mortar they are much greater." [3]

At present all standard specifications leave much to be desired. A Government committee appointed to investigate the quality of a certain brand of cement, after much consultation with engineers, chemists, contractors and manufucturers, introduced its final report with these remarks:

> "There are no standard specifications which are regarded as absolutely correct. All tests are approximations and must be interpreted in accordance with the specifications in use, and with due regard to the purpose for which the cement will be used.
>
> "There is no practical difference between the qualities and properties of a rejected and of an accepted cement in the immediate vicinity of the limits set by specifications." [4]

It follows that the engineer may be in much doubt as to whether to reject or accept a cement.

> "It must be recognized, however, that cement specifications are not for average results, but are intended to cover the lowest limit which can be allowed in the work and to provide for lack of uniformity in testing as well as in real quality." [5]

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[2] Sabin, Louis Carlton: Cement and Concrete. New York (1905), 30.

[3] Spalding, Frederick C.: Hydraulic Cement. New York (1904), 115.

[4] Final report of cement investigation committee appointed by Executive Order No. 60, 1907.—The Government of the Philippine Islands.

[5] Taylor and Thompson: Concrete, Plain and Reinforced. New York (1907), 99.

Such a conclusion may be satisfactory to the engineer, but should the tests be close to the margin specified for acceptance, the selling agent is sure to protest and order a retest of the material. He may allow the original tester to retest the cement, or he may send the samples to one of the many commercial laboratories whose reputation for high results in cement testing is well established. The retesting may produce satisfactory results in either case owing to the weakness of all cement specifications. "It is not to be inferred however that the highest results are necessarily the outcome of the greatest skill. As a rule the most expert and reliable operators get only moderate strength for the best material." [6]

Such a condition of cement testing is very deplorable. Unless specifications guarantee an accuracy within 10 per cent, the greatest efficiency of a cement laboratory is also lost, as the mere mechanical routine testing of various brands of cement should be the least important part of its work and satisfactorily to accomplish the more important object, namely a systematic study of the peculiar effects of climatic conditions upon them, a variation factor of not more than 10 per cent is essential.

Sabin states that "the chief object of testing cement is to arrange the various products in their true order of merit. Cement is at present used in a very crude way and it is only in exceptional cases that poor quality of material may be detected in the completed structure. This is sufficient reason why so few failures can be found in cement work which may be attributed to the poor quality of the cement. But in the more economical manner in which the material is, even now, being used, it is absolutely essential to know what its future behavior will be." [7]

We believe that the inefficiency of all American specifications lies in the fact that they do not outline sufficiently in detail the minor considerations and operations, and that to these minor details, owing to the peculiar and sensitive character of cement, is readily attributed a possible variation in the results of testing of 30 to 40 per cent. There are certain qualities in cement manipulation that can not be controlled, such as the size, shape and intermingling of crystals, nonhomogeneous voids in sand briquettes, unequal action of the water upon the hardening of briquettes, etc., but we believe that by far the greater variation is caused by the different manner in which different laboratories interpret the minor details of manipulation and treatment; and we also believe that if specifications were more explicit in this respect it would be safe to predict that different laboratories would agree within 10 per cent. This assumption is supported by the well-known fact that the system of the individual laboratory usually produces fairly uniform results, but a comparison between different laboratories which differ only in those details not explicitly treated in the specifications, often shows the most startling inconsistencies. To be more explicit, we will give, for example, the following tests made under the Army Specifications for 1902:

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[6] Spalding, Frederick C.: Hydraulic Cement. New York (1904), 160.

[7] Cement and Concrete. New York (1905), 82.

Two operators of considerable experience were ordered to test according to these specifications a shipment of 1,000 barrels of cement under dispute. Fifty samples, each representing one barrel, were taken at random, tested, and the figures tabulated as shown by the accompanying diagrams numbers 1 and 2 and by Table I.

TABLE I.—*Showing the variations from the mean of 200 breaks of each of the four sets of briquettes made by the testers.*

Tester.	Neat (200 each).		Mortar, 1 to 3 (200 each).	
	7-day.	28-day.	7-day.	28-day.
A	502.4	601.8	143	220.6
B	566.8	641.3	164	235.3
Mean	534.6	621.6	153.5	228.0
Difference	32.2	19.8	10.5	7.4
Per cent	±6.0	±3.2	6.8	3.2

Increase from 7 to 28 day tests.

	Neat.[a]		Mortar, 1 to 3.[b]	
	A.	B.	A.	B.
Pounds	99.4	74.4	77.6	71.3
Per cent	19.8	13.1	54.3	43.5

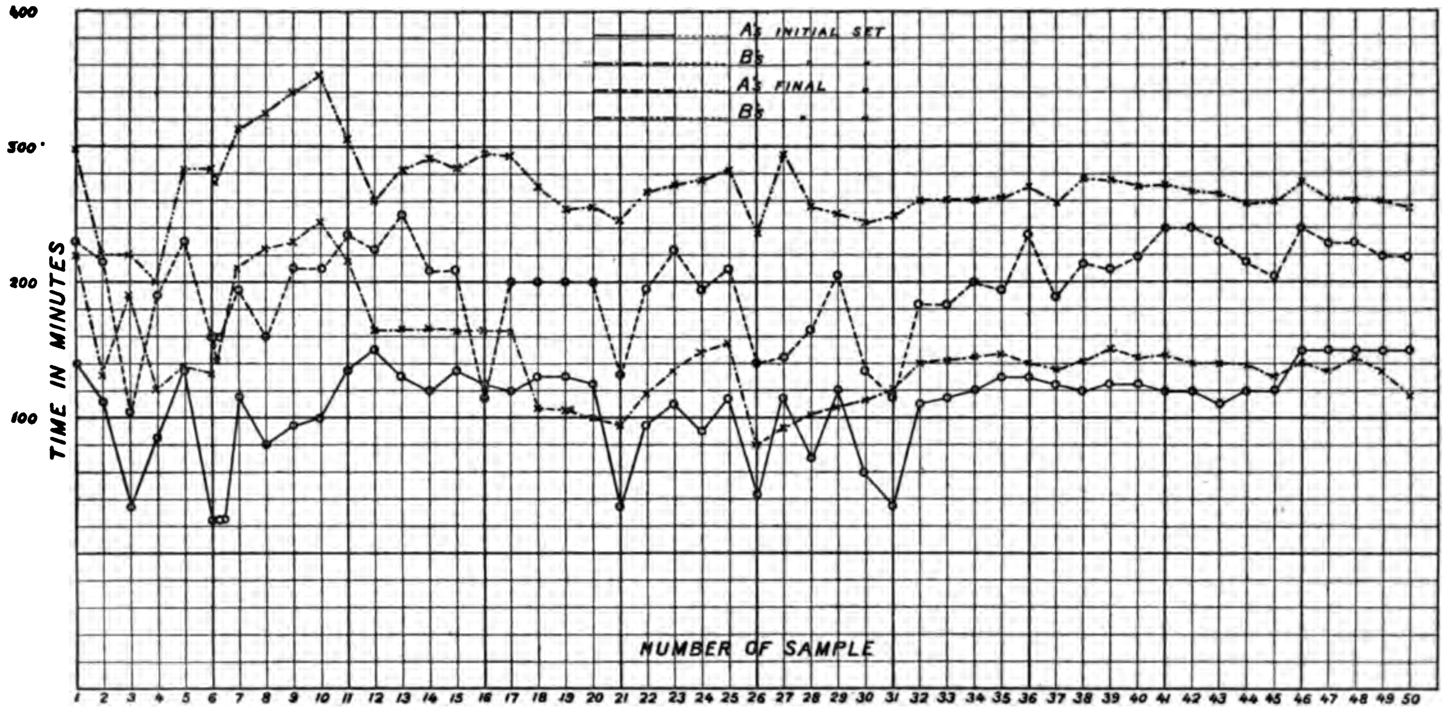
[a] Increase desired by specifications: 20 per cent.
[b] Increase desired by specifications; 57 per cent.

The fineness (through 100-mesh sieve) varied from 94.2 to 97.3.

The specific gravity dried at 110° in all cases, was below 3.08 and ranged from 3.02 to 3.07.

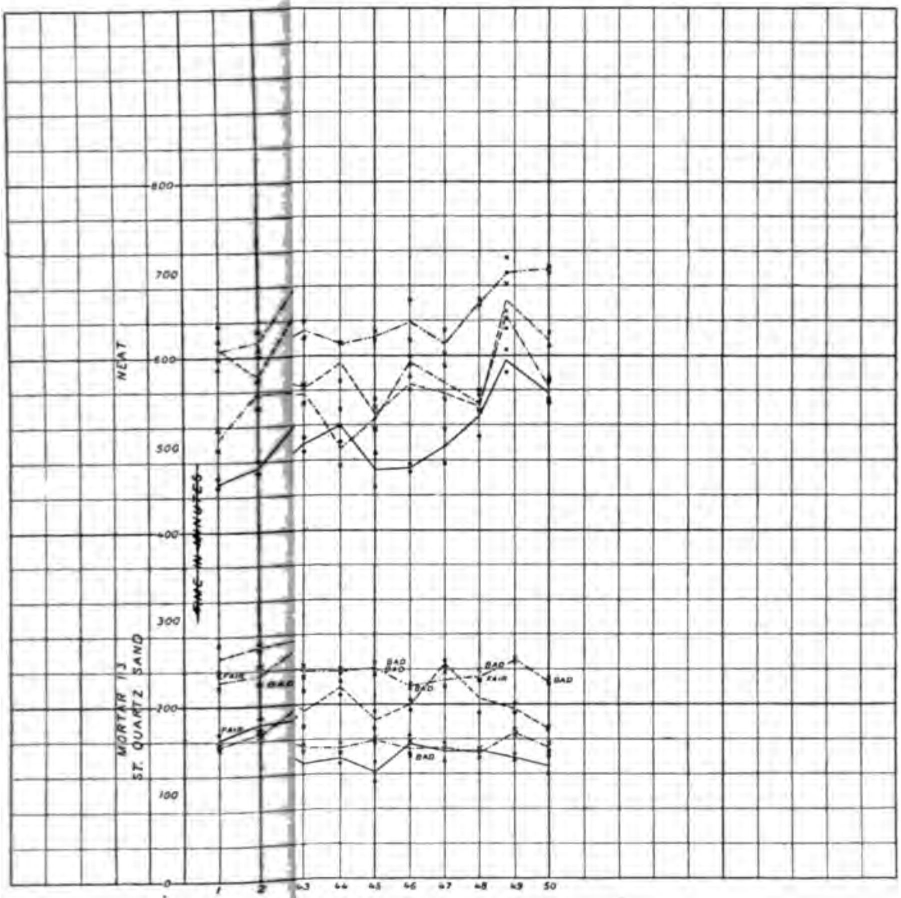
Space will not permit of discussion in detail of the methods used by each tester, except to say that A used the automatic tamper described below and applied the blows differently than did B, who used the ordinary tamper; A's briquettes were placed in a wet closet, B used the damp cloth; A's briquettes were also always under water, kept running for a few hours each day; B siphoned the water from the pans and then refilled them, thus exposing the briquettes to air for about 10 minutes each time. All these differences were in accordance with specifications, as the minor details of testing were indefinite enough to allow them.

One operator, A, always obtained lower results on an average than B, but B did not show the gain in strength between the 7 and 28 day tests that the cement was capable of. Evidently, B's system gave abnormally high 7-day tests, and therefore 28-day breaks showed little increase. However, notwithstanding these differences, the variation between the samples themselves is also clearly evident.



TIME OF SETTING

DIAGRAM NO. 1.


NEAT
MORTAR 1:3
ST. QUARTZ SAND
TIME IN MINUTES
800
700
600
500
400
300
200
100
0
1
2
43
44
45
46
47
48
49
50
FAIR
BAD

The diagram calls attention to the lack of uniformity in the results attained in each sample. The differences in the tensile strength are not only between the two testers, but also brought out by the same individual: those in the increase of strength with age, the failure on the part of one tester to obtain good breaks in many instances, and the great variation in the time of setting, are all apparent; yet both operators worked carefully and in strict accordance with the United States Army specifications. The committee in charge, after thoroughly investigating the methods of the two operators, reported as follows:

> "The methods followed by each cement tester differ slightly in certain details, but the differences are not regarded by the committee as important or as in violation of the purport of the specifications; and the results obtained in each laboratory are regarded as fair, equitable and reasonable to both manufacturer and user."[6]

Even careful inspection of these charts would probably convince almost anyone that the tests, as they stand, are practically useless; that one of these testers, or even both, were inefficient; or that the cement itself was of a most peculiar quality. However, as will be shown, the whole inconsistency was due to a cause the elimination of which the specifications do not even mention. It appears that the work of the testers for time of setting, 28-day neat and sand strength, and specific gravity determinations, was accurate and true to the quality of the cement at the time it was tested. The cause of the great variability so evident in diagrams numbers 1 and 2, was due to the fact that each tester worked the cement after it had undergone various degrees of exposure to aëration, and that the influence of this factor produced very marked changes in the quality of the cement.

THE EFFECTS OF AËRATION.

Most of the cement specifications now in use devote considerable space to the manner in which the samples should be taken, but they all neglect to state how these samples shall be stored and preserved until tested. As a result, they may be sent to the laboratory in wooden or paper boxes, paper or cloth bags, tin cans, galvanized-iron cans, glass jars, etc. The cloth and paper may be thin or thick, and the cans, jars and boxes may have tightly or loosely fitting covers, or even no covers at all. These samples may be tested as soon as they are received at the laboratory or, owing to the amount of routine work already on hand, they may stand for some days before being worked. As a result of all these conditions the cement may have been subjected to unequal aëration and its characteristics changed accordingly; this change has often been sufficient to alter the resulting tests from satisfactory to unsatisfactory.

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[6] Final report of cement investigation committee appointed by Executive Order No. 60, 1907.—The Government of the Philippine Islands.

The literature on the subject of cement is filled with information on the effects of aëration.[9] Cements high in lime or those which are "unsound" due to the presence of free lime, are improved by exposure to the air, but cements high in alumina, especially if lightly burned, are apt to become quick setting and otherwise dangerous under the same treatment. This is especially true in the tropics as "aluminous cements are readily subject to alteration in surroundings exposed to alternate dryness and humidity and also when exposed to a high temperature."[10]

Cements are encountered, the fineness and soundness of which may be very satisfactory throughout, but the specific gravity, time of setting and tensile strength (the 1 to 3 mortar especially) may vary from one extreme to the other. None of the pats may warp or disintegrate, even during steam and air exposures, so that perfect soundness may be a characteristic of such material. In fact, it is possible for a pat to remain at a red heat for several hours before it disintegrates in any marked decree. Cement of this class, according to chemical analysis made from time to time, proved itself to have a uniform composition in all respects except the loss on ignition, which varied from 1 to 6 per cent. The silica content was uniformly low and the alumina and iron high. It is hardly necessary to add that every known precaution was taken to secure uniform results.

Experience in this laboratory has demonstrated that in most instances variations such as those mentioned are encountered in cement samples which have been received in thin paper bags, or which had otherwise been exposed to the air; and that cement received for testing in closely covered cans and boxes and not subsequently exposed to the air, usually gave very acceptable, uniformly good results. These conclusions are emphasized by the following tables:

TABLE II.—*Characteristic examples of tests of cement stored in cans.*[11]

Sample No.	Mortar, 1 to 3.		Sample No.	Mortar, 1 to 3.	
	7-day.	28-day.		7-day.	28-day.
D5-2	240	289	BB13	225	307
D5-4	210	265	BB14	238	295
D5-6	210	305	BB15	205	299
D5-8	193	300	BB16	212	260
D5-10	210	315	BB17	248	288

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[9] Meade: *Chem. Eng.* (1907), 5, 341; Taylor and Thompson: Concrete, Plain and Reinforced, New York (1907), 62; Spalding, Frederick C.: Hydraulic Cement, New York (1904), 4, 56, 80; Candlot, M.: Cement et Chaux Hydrauliques, Paris, 1891.

[10] Spalding, Frederick C.: Hydraulic Cement. New York (1904), 81.

[11] The setting time in all of these cements was satisfactory and uniform.

TABLE III.—*Variations in the same brand of cement received in paper bags.*

[Mortar, 1 to 3.]

Sample No.	Highest.		Sample No.	Average.		Sample No.	Lowest.	
	7-day.	28-day.		7-day.	28-day.		7-day.	28-day.
D1-1	187	269	C5-1	168	260	B9-1	126	194
D1-2	179	259	C5-2	141	214	B9-2	166	240
D1-3	191	259	C5-3	141	210	B9-3	140	181
D1-4	180	228	C5-4	139	232	B9-4	143	171
D1-5	169	234	C5-5	144	202	B9-5	106	125
D1-6	176	245	C5-6	195	257	B9-6	138	193
D1-7	168	221	C5-7	180	238	B9-7	135	186
D1-8	184	257	C5-8	145	224	B9-8	175	178
D1-9	174	234	C5-9	168	204	B9-9	103	181
D1-10	182	234	C5-10	145	210	B9-10	148	185

TABLE IV.—*Time of setting.*

Sample No.	Initial set.		Final set.		Sample No.	Initial set.		Final set.	
	h.	*m.*	*h.*	*m.*		*h.*	*m.*	*h.*	*m.*
B9-1	1	00	2	00	B9-6		23	2	30
B9-2	1	30	2	30	B9-7		50	1	35
B9-3		50	2	10	B9-8				
B9-4		48	1	33	B9-9		48	1	27
B9-5		35	1	10	B9-10		31	1	38

The above results led us to investigate more specifically the effect of air exposure on this class of cement. In Table V the depreciating effect upon the mortar of freely exposing a small amount of cement (about 400 grams) to the air in open jars for ten days is clearly shown. All mortar mixtures made from cement fresh from the sample package, dried or undried, and exposed to the air not longer than eighteen hours, did not set before the molding was completed and passed in tensile strength. All mortar mixtures made from cement exposed to the air for ten days, set before the molding was completed and therefore failed in tensile strength.

TABLE V.—*Test with dried and undried cement taken from paper bags.*

[Mortar, 1 to 3. Temperature of room during molding and setting, 29° to 30° C.]

Sample No. (same brand).	Condition.	Condition of mortar when molded.	Age.	Pounds per square inch.	Water used.
			Days.		*Per cent.*
F3-9	Dried and exposed to air 10 days	Set in 10 minutes	7	79	12.5
F3-9	Dried and exposed to air 10 days	Set in 12 minutes	7	98	14
F3-9	Dried and taken fresh from sample package.	Not set in 20 minutes.	7	186	14
F4-4	Dried and exposed to air 10 days	Set in 12 minutes	7	70	12.5
F4-4	Undried, fresh from sample package	Not set in 20 minutes	7	182	12.5
F4-4	Fresh from sample heated at 100° C., exposed 1 day.	Not set in 20 minutes	6	157	12.5
F4-4	Fresh from package undried	Not set in 20 minutes	7	([a])	12.5
F4-8	Dried and exposed to air 10 days	Set in 10 minutes	7	92	12.5
F4-8	Dried and exposed to air 10 days	Set in 12 minutes	7	101	14
F4-9	Undried, fresh from sample package	Not set in 20 minutes	7	166	----------
F4-10				178	12.5

[a] *8 briquettes*—146 lowest 183 highest.

Percentage of water evaporated from F4-4 in drying was 0.66.

In all cases not specified the highest of four good breaks is recorded.

These results demonstrate that heating did not cause quick setting, and low tensile strength, but exposure to air in open jars for ten days did. Table Va illustrates the same action:

TABLE Va.

[28 days; mortar, 1 to 3.]

Sample No.	Water.	Stored.	After 10 days.	After 30 days.	After 50 days.
	Per ct.				
X1	12½	Covered can	315	302	295
X1	12½	Uncovered can	247	205	158
X2	12½	Covered can	300	[a]298	202
X2	12½	Uncovered can	245	198	147

[a] Cover removed from can on thirtieth day.

The samples included in the next table were received at the laboratory in paper sacks on the 27th of the month. The next morning the two sacks comprising each sample were screened and well mixed. One half of each sample was then put into a tightly covered, galvanized-iron can, and the other half put back into the original bag. The time of setting was taken after seven, eleven, and twenty-four days with the results given in Table VI.

Table VI.—*Comparison of results of samples in paper bags and in closed cans.*[a]

Time gauged.	Worked after 7 days.						Temperature during—	
	Sample No.	Stored in—	Water.	Initial set.		Condition of paste.	Gauging.	Setting.
A. M.			*Per ct.*	*h.*	*m.*		°C.	°C.
8.10	1	Can	21	1	10	Plastic	27	27 -29.5
8.20	2	Bag	21		60	do	27	27 -29.5
8.30	3	Can	21	1	22	do	27	27 -29.5
8.40	4	Bag	21		35	do	27.5	27.5-29.5
8.50	5	Can	21		60	do	27.5	27.5-29.5
9.00	6	Bag	21		12	do	27.5	27.5-29.5
9.10	7	Can	21	1	10	do	27.5	27.5-29.5
9.20	8	Bag	21		20	do	28	28 -29.5
9.30	9	Can	21		55	do	28	28 -29.5
9.40	10	Bag	21		13	do	28	28 -29.5
	Sample No. 8, worked after 11 days.							
8.25	8	Can	21	1	10	Plastic	27.5	27.5-30
8.35	8	Bag	21		17	do	27.5	27.5-30
8.45	8	Can	22	1	25	do	27.5	27.5-30
9.00	8	Bag	22		20	do	27.5	27.5-30
9.10	8	Can	24	1	30	Too plastic to hold its shape.	27.5	27.5-30
9.20	8	Bag	24		38		27.5	27.5-30
	Worked after 24 days.							
8.30	2	Bag	22		21	Very plastic	28	28 -30
8.40	3	Can	22	2	30	do	28	28 -30
8.55	3	Bag	22		20	do	28	28 -30
9.05	4	Bag	22	1	30	do	28	28 -30
9.15	4	Can	22	2	30	do	28	28 -30
9.25	8	Can	22	1	30	do	28	28 -30
9.35	8	Bag	22		23	do	28	28 -30

[a] All pats were made by the same operator by the Gillmore needle method described below. Before weighing, the original samples were thoroughly mixed.

Chemical analysis of number 8 sampled on the eleventh day gave:

TABLE VII.—*Analysis on eleventh day.*

Constituent.	From bag.	From can.
	Per cent.	*Per cent.*
Silica	19.80	20.24
Alumina	8.33	8.50
Iron oxide	2.75	2.98
Calcium oxide	63.44	63.32
Magnesium oxide	2.25	2.15
Moisture (110°)	0.32	0.14
Loss on ignition	3.14	2.52
Sulphuric acid (SO_3)	0.43	0.42

TABLE VIII.—*Moisture, loss on ignition and carbonic acid.*

Sample No. 8.	On twenty-fourth day cement from—		Difference.
	Can.	Bag.	
	Per cent.	*Per cent.*	*Per cent.*
Moisture at 110°	0.14	0.40	0.26
Loss on ignition after drying	2.63	3.92	1.29
Carbonic acid (CO_2)	1.14	1.64	0.50
Combined water	1.49	2.28	0.79

The rapidity with which this absorption of carbon dioxide and water may take place (the local climatic conditions being those of the early dry season) is shown in Table IX.

Two different brands were investigated, and in each case 50 grams of cement were taken from each of the samples specified, and put into 100 cubic centimeter beakers. These were accurately weighed and the free moisture then thoroughly driven off by four hours' heating at 130° C. The beakers were then allowed to stand in the balance room, open to the air, but protected from dust by paper coverings. The gain in weight was noted at the intervals of time designated. At the end of twenty-eight and one-half days, the moisture was again driven off by continued heating at 130° C. and the amount of water absorbed subtracted from the total absorption. The samples were again reheated after thirty-five days' additional exposure. The results obtained in detail are as follows:

TABLE IX.—*Changes in weight on exposure to air.*

Brand No.	Sample No.	Loss when received on heating at 130° C.—moisture.	Gain in weight on exposure to air—carbon dioxide moisture, and water of hydration.														Lost on heating at 130° C.—moisture.	Total absorption other than moisture.	Gain in weight for 35 days, after second heating.	Lost on heating at 130° C. after 35 days=moisture.	Total absorption other than moisture for 63½ days from the beginning.
			Hours.							Days.											
			18.	18.	6.	18.	24.	24.	48.	1.	1.	1.	1.	5.	7.	6.					
		P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
1	F6-1[a]	0.74	0.19	0.15	0.07	0.15	0.19	0.17	0.30	0.13	0.9	0.11	0.10	0.45	0.44	0.32	1.07	1.77	1.07	0.78	2.01
1	F6-3[a]	0.64	0.18	0.12	0.02	0.14	0.16	0.15	0.29	0.11	0.9	0.10	0.10	0.44	0.45	0.32	1.10	1.62	1.11	0.78	1.95
1	F6-5[a]	0.77	0.15	0.12	0.04	0.18	0.19	0.16	0.32	0.13	0.9	0.11	0.11	0.47	0.45	0.34	1.00	1.95	1.15	0.68	2.42
1	F6-7[a]	0.71	0.14	0.11	0.05	0.15	0.17	0.17	0.30	0.13	0.8	0.10	0.10	0.40	0.43	0.31	1.01	1.74	1.25	0.80	2.19
1	F6-9[a]	0.74	0.15	0.11	0.04	0.16	0.17	0.17	0.30	0.11	0.10	0.10	0.10	0.43	0.43	0.30	0.96	1.76	1.28	0.77	2.24
2	L208[b]	0.36	0.12	0.06	0.02	0.13	0.17	0.14	0.28	0.12	0.10	0.11	0.11	0.46	0.49	0.39	0.84	1.97	1.02	0.59	2.40
2	L213[b]	0.42	0.10	0.06	0.03	0.15	0.17	0.14	0.29	0.12	0.11	0.11	0.11	0.48	0.49	0.37	0.81	2.00	1.15	0.67	2.48
2	L217[b]	0.47	0.10	0.08	0.03	0.14	0.17	0.11	0.31	0.12	0.10	0.11	0.11	0.47	0.49	0.35	0.83	1.91	1.01	0.63	2.89

[a] Received in bag.

[b] Received in can.

TABLE X.—*After exposure for sixty-five and one-half days.*

Sample No.	Loss on ignition.	Carbonic acid (CO_2).
	Per cent.	*Per cent.*
F6-1	4.67	2.40
L208	4.25	2.42

The rapidity with which this action will progress depends upon climatic conditions, upon the nature of the cement itself and upon the ratio between the volume of the cement and the surface exposed. The action may take place very rapidly on the exposed surfaces, and yet penetrate into the mass very slowly.

A well-mixed cement was stored in a uncovered can for one month. Cement taken not lower than half an inch from the upper surface set in twenty minutes, while cement taken 6 inches below this surface did not set until two hours. It is therefore absolutely essential in order to secure uniform results from the same sample thoroughly to mix the cement before weighing; otherwise a wide discrepancy between the specific gravity, time of setting, and tensile strength may result which could not otherwise be accounted for.

The above data are considered sufficient to illustrate the effects of aëration, although in this laboratory we have many more experiments proving the same facts. It may be well to state that cements have been encountered which do not change to any appreciable extent after exposure for several weeks.

It has been shown (Table VI, can 8; eleven and twenty-four days) that cement, otherwise susceptible to a marked change by exposure to air, when preserved in closely covered galvanized-iron cans will be little affected by storage; and that thin paper bags do not eliminate the atmospheric influences. It has also been shown that the characteristics of a cement often undergo a change upon exposure which may be sufficient to make failures of otherwise acceptable tests. Therefore, it is evident that no system of cement testing, however accurate, will insure uniform or even comparative results until a proper, specified preservation of the samples after they are taken from stock is made compulsory.

As a result of the considerations given above, it would seem necessary so to modify the ordinary procedure that the quantity of the cement deemed necessary for the desired tests should be freely exposed to the atmosphere of the laboratory for seven days in a layer 1 inch deep, in order to determine the effects of aëration. A comparison of the specific gravity, setting time, and loss on ignition of the cement before and after exposure, will give valuable indications as to its nature. The determinations made before exposure will be consistent with the quality of the cement at the time the stock was sampled, and the second treatment will show the qualities liable to be developed by subsequent storage. If the effect of exposure is considerable, troublesome variability of the brand may be readily attributed to this cause and the manufacturer will then know how to improve his product accordingly.

Changes caused by the atmosphere penetrate very slowly into the mass of the cement in barrels, because the wooden staves and heads keep the air from the product to a considerable extent and the mass of material is large, therefore, alterations which may develop very rapidly in a small sample exposed in the laboratory would not take place in the barrel until a much longer period of time had elapsed. Spalding[12] states that "the effect upon cement of retaining it a long time before using depends upon the nature of the cement and the method of keeping it. When the cement is inclosed so as to prevent the access of air, as in barrels, it may usually be preserved for a considerable time without experiencing any alteration, provided it is kept dry."

The fact that cements stored in good barrels undergo very little change by a month's seasoning is illustrated by the original and the re-test of the following cement, the results of which are recorded in Table XI. The samples for the re-test were taken a month after the original ones. All the samples were protected from aëration before testing, and the re-test gave only slightly lower results, although subsequent experiments showed that the cement rapidly deteriorated in time of setting and tensile strength when subjected to air exposure.

Table XI.[a]—*Original and re-test (one month later) of cement stored in barrels.*

ORIGINAL TEST.

Sample No.	Fineness.	Sp. gr.	Initial set.	Final set.	Tensile strength, neat.			Tensile strength, 1:3 mortar.	
					1 day.	7 days.	28 days.	7 days.	28 days.
			h. m.	*h. m.*					
1	95.8	3.07	2 10	5 00	392	516	640	240	285
2	96.5	3.07	2 15	5 10	351	563	605	200	278
3	96.2	3.08	2 10	5 00	354	532	687	221	300
4	96.0	3.08	2 10	5 00	351	558	610	232	296
5	97.0	3.08	2 00	5 00	312	542	653	222	300
Average	96.3	3.08	2 9	5 2	352	542	639	223	292

RE-TEST ONE MONTH LATER.

Sample No.	Fineness.	Sp. gr.	Initial set.	Final set.	Tensile strength, neat.			Tensile strength, 1:3 mortar.	
					1 day.	7 days.	28 days.	7 days.	28 days.
1	94.5	3.08	2 25	4 20	322	570	594	210	283
2	94.0	3.08	2 20	4 15	349	566	621	195	278
3	95.0	3.08	2 20	4 40	312	531	583	200	300
4	94.7	3.08	2 10	4 35	325	559	612	199	281
Average	94.5	3.08	2 19	4 28	327	556	602	201	285

[a] The soundness of all samples was satisfactory.

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[12] *Ibid.*, 67.

Many engineers maintain with good judgment that a cement should not develop dangerous properties on exposure to the air and if it does so it merits rejection, especially if the unexposed samples show irregularity, since it is only practicable to test one barrel out of every ten or twenty in stock. It is also true that barrels often become broken in shipment, and should the cement which is so received develop dangerous properties, the strength of a whole structure might be weakened by its use.

Portions of the original samples of the cement the tests of which are recorded by diagrams numbers 1 and 2 were preserved and the tests after aëration in paper bags are shown in Table XII. All of these tests were manipulated in the same laboratory, and they show that this cement is more or less readily subject to the influence of aëration.

TABLE XII.—*Test of cement shown in diagrams numbers 1 and 2, after aëration in paper bags.*

Sample No.	Initial set, in minutes, after storage in paper bags for the times given.			Range of temperature during setting.	Specific gravity after—		
					Storage in bags.		Heating to red heat, 23 weeks' exposure.
	1 day.[a]	34 days.[a]	23 weeks.[b]		34 days.	23 weeks.	
				°C.			
X1	220	140	45	27–30	--------	3.02	3.14
X2	130	110	65	27–30	3.06	3.03	
X4	120	85	30	27–30	3.02	3.02	3.14

[a] 21 per cent water. [b] 22 per cent water.

THE DISPOSAL OF CAKED CEMENT.

It is usually specified that cement shall be screened through a 20-mesh sieve and thoroughly mixed before testing. The object of the sieving is to break up lumps and remove wood splinters, stones and other foreign substances. Such a procedure is of course proper. However, under certain conditions, the disposal of caked cement when it is present in considerable quantity should be more fully described.

Cement literature has repeatedly pointed out that the tensile strength of a caked cement is considerably below that of the original material before it formed lumps. This is due to the absorption of moisture and the subsequent partial setting. The difference that may result from such a change is illustrated in Table XIII, which gives the tensile strength developed by two samples of the same cement, one free from lumps and the other caked.

TABLE XIII.[13]

Condition.	Mixture.	7-day.	28-day.	3 months.	1 year.	2 years.	3 years.
All lumps	Neat	417	589	690	705	739	719
No lumps		686	756	798	858	857	805
All lumps	Mortar	131	244	326	373	372	373
No lumps		192	330	380	430	449	450

The disposal of these lumps then, especially those which are too hard to be broken up in the process of sieving, may exert considerable influence in the tensile strength obtained. If one tester pulverizes the hard lumps and mixes this powder with the original sample, and the other simply throws them away, uniform results can not be expected.

Should the cake be present in sufficient quantity to affect the tensile strength appreciably, the person requesting the tests should be notified of this condition. The presence of the cake may not be due to any fault or carelessness on the manufacturer's part. Improper storage while in the hands of the engineer or contractor may have caused it. Instances are also on record in this laboratory where caking was induced in the samples after they were taken from the stock. The samples were taken during a rain storm and through carelessness and incompetency on the part of the one handling them, they were allowed to get wet.

If specifications are to guarantee uniform and just results in all cases, the treatment of caked cement must be more fully described than it has heretofore.

INFLUENCE OF TEMPERATURE ON TIME OF SETTING.

The general rule for all cements is that increase of temperature increases the rate of setting. However, there is no fixed ratio between the temperature increase and the accelerated setting produced by it. The published reports of skilled operators vary in this respect, and L. Tetmaier,[14] after years of the most careful work was forced to admit that "different cements are differently influenced by alteration of temperature * * * and it is scarcely possible to deduce a general law for even one class of cements."

The results we have obtained on the setting time of various cements, worked in the cold-storage room and at local temperature, have shown that the samples, in this respect, could be divided into three classes:

1. Slow setting cements, little affected by a variation of temperature from 20° to 30° C.

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[13] Griesenauer, *Eng. News* (1906), 55, 68.

[14] *Soc. Chem. Industry* (1893), 12, 1036.

2. Cements which are slow setting at 20° C. but quick setting at 30° C.
3. Cements which are quick setting at 20° C. and also at 30° C.

As these results were obtained while we were endeavoring to determine the variation which this climate might cause in tests which according to American standard specifications are at about 20° C., we will publish them in full in Tables XIV, XV, XVI, and XVII.

In all the following determinations the cement was sieved and then very thoroughly mixed. To eliminate any effect of unequal atmospheric exposure each sample of 500 grams was put into a dry, clean bottle and tightly corked until used. In gauging, the water was allowed to soak in for one minute, and then the paste was vigorously troweled for four additional minutes.

TABLE XIV.—*Class No. 1, slow-setting cements, little affected by variations of temperature.*

Bottle No.	Temperature when made.			Temperature of room during setting.	Water.	Initial set.	Final set.	Condition of paste.
	Cement.	Water.	Room.					
	°C.	*°C.*	*°C.*	*°C.*	*Per cent.*	*h. m.*	*h. m.*	
1	19	19	19	19 -19.5	20.66	2 35	6 15	Slightly plastic.
2	19	19	19	19 -19.5	21.66	2 45	6 15	Plastic.
3	19	19	19.5	19 -19.5	22.66	3 00	6 20	Do.
4	19	19	19.5	19 -19.5	23.66	3 00	6 20	Very plastic.
5	32	32	31	32 -32.5	20.66	2 35	6 20	Plastic.
6	28	28	28.5	28.5-31	21.66	2 20	4 20	Do.
7	28	28	28.5	28.5-31	22.66	2 20	4 30	Do.
8	28.5	28.5	28.5	28.5-31	23.66	2 55	5 35	Very plastic.
9	29	29	30	30 -31	23.66	2 25	4 15	Do.

TABLE XV.—*Class No. 2, slow-setting cements at 20°, quick-setting at 30° C.*

Bottle No.	Temperature when made.			Temperature of room during setting.	Water.	Initial set.	Final set.	Condition of paste.
	Cement.	Water.	Room.					
	°C.	*°C.*	*°C.*	*°C.*	*Per cent.*	*h. m.*	*h. m.*	
1	31	31	31	31 -33	21	([a])	([a])	
2	31	31	31	31 -33	22	25	2 30	Slightly plastic.
3	28	28	28.5	28.5-30	21.66	21	2 50	Do.
4	28	28	28.5	28.5-30	22.66	28	3 00	Plastic.
5	28.5	28.5	29	29 -30	23.66	32	3 10	Very plastic.
6	19.5	19.5	19.5	19.5-20.5	21.66	2 32	3 40	Slightly plastic.
7	19.5	19.5	19.5	19.5-20.5	22.66	3 30	4 40	Plastic.
8	19.5	19.5	19.5	19.5-20.5	23.66	3 50	5 00	Very plastic.

[a] Impossible to make pat.

To determine the effect of gauging in the cold-storage room and setting in the laboratory, and vice versa, two pats were made from each paste and one subjected to the change in temperature; the results are recorded in Table XVI.

TABLE XVI.

Bottle No.	Pat No.	Temperature when made.			Temperature of room during setting.	Water.	Initial set.	Final set.	Condition of paste.
		Cement.	Water.	Room.					
		°C.	°C.	°C.	°C.	Per cent.	h. m.	h. m.	
1	1	20.5	20.5	21.5	20.5-22	22.66	2 15	--------	Plastic.
	2	20.5	20.5	21.5	32 -32	22.66	55	2 10	Do.
2	1	20.5	20.5	21.5	20.5-22	22.66	2 20	--------	Do.
	2	20.5	20.5	21.5	32 -31.5	22.66	60	2 30	Do.
3	1	32	20	32	32 -31.5	22.66	26	1 55	Do.
	2	32	20	32	20.5-22	22.66	50	--------	Do.
4	1	32	32	32	32 -31.5	22.66	21	1 21	Do.
	2	32	32	32	21.0-22.0	22.66	38	--------	Do.

TABLE XVII.—*Class III, cements which are quick setting at 20° and also at 30°.*[15]

Bottle No.	Cement.	Temperature of water, cement, and room.	Temperature of room during setting.	Water.	Initial set.	Condition of paste.
		°C.	°C.	Per cent.	h. m.	
1 and 9	A	17-18	17.5-18	22	1 40	Plastic.
2 and 10	A	29-30	29 -30.5	22	1 20	Do.
3 and 11	A	17-18	17.5-18	21	1 25	Do.
4 and 12	A	29-30.	29 -30.5	21	1 20	Do.
5 and 13	A	17-18	17.5-18	20	40	Slightly plastic.
6 and 14	A	29-30	29 -30.5	20	45	Plastic.
7 and 15	A	17-18	------------	19	([a])	([a])
8 and 16	A	29-30	------------	19	([a])	([a])
1 and 3	B	17-18	17 -18.5	24	28	Very plastic.
2 and 4	B	29-30	29 -31	24	24	Do.

[a] Impossible to make pat.

Remark.—Pastes made with 20 per cent of water were more plastic when made at 30° than at 17°.

MOIST-AIR CLOSET.

Another possible source of error which may be accountable for considerable variation may develop during the moist-air treatment.

Most specifications allow the briquettes to be stored for the first twenty-four hours in a moist-air closet or under a damp cloth. Moist-air closets are given the preference, as unequal drying often occurs in using the damp cloth. A well-constructed moist-air closet is essential to uniform results.

One condition in the use of a moist-air closet that is liable to have considerable influence upon the result of the cement tests should be taken into consideration. This is produced by the heating of the cement after it is gauged and molded. Many cements heat considerably at some period of the stage of early setting and hardening, the rise in temperature often being as much as 10°C.; it may take place in five minutes, or it may not occur until many hours after the gauging.

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[15] This table also shows the marked effect that 1 per cent of water more or less, will produce upon the plasticity and time of setting of some cements.

C. Prussing[16] states that "many slow setting cements of excellent quality begin to set after five or six hours and then set completely in one hour, giving a rise of temperature of 5° to 7°C." The heat generated by briquettes placed under a damp cloth is not confined, as it is readily conducted away into the surrounding atmosphere. Moist-air closets are constructed to insulate the interior from outside heat influences as much as possible, and as a result the heat generated by the briquettes is confined; so that in a cubical moist-air closet of 2 feet on the side which was used to store briquettes after they were removed from the molds, the temperature often rose to 40° (30° being room temperature) when it held from 80 to 100 briquettes. A number of slow-setting briquettes made at different, successive intervals of time, or worse still a mixture of quick, normal, and slow-setting cements, will under these conditions not be subjected to the same uniform temperature, or to a temperature change that is characteristic of it during its most critical setting and hardening period; and the same is true of the storage of pats made for the time of setting when many are placed in one compartment after gauging.

It is well known that the temperature conditions under which cement sets and hardens will influence its tensile strength. Therefore, the practice of storing numerous briquettes in one compartment of a moist-air closet is very liable to cause abnormal one, seven and twenty-eight day breaks of some of them. Pats for time of setting similarly stored may be also affected to such a degree that an otherwise slow-setting cement may become quick setting.

We suggest two ways of overcoming this objectional feature of the ordinary closet. The heat generated by the setting cements may be conducted away by means of a forced ventilation of air saturated with moisture; or only briquettes and setting pats of the same cement made at practically the same time should be placed in a small, insulated compartment. The former method will maintain the interior of the compartment at nearly the same temperature as that of the laboratory, while the latter will meet the conditions of actual service, as the heat generated by the cement is not readily conducted away. Laboratory tests should coincide as closely as is possible with the actual conditions of construction work, where large volumes of concrete are tamped into wooden frames. The heat generated in such a large mass (especially in the center of it) is not conducted away by ventilation and it is in fact partly insulated by the wooden molds. Therefore, a moist-air closet formed of several small, insulated compartments, each with its own pan of water, is best adapted for the purpose. Such a moist-air closet has been constructed for this laboratory.

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[16] *Thonind. Zeit.* (1894), 18, 251.

Standard cement specifications should include a definite form of moist-air closet with a complete description of the materials for its construction, its dimensions, and directions for its use; otherwise one source of the so-called personal error will persist.

TIME OF SETTING.

The American Society has adopted the Vicat needle method for determinations of the time of setting. It seems to be the general impression that the Gillmore method does not insure the desired accuracy, and many cement testers will regret that such a convenient and time-saving process has been supplanted by a more cumbersome one; still the Gillmore method, if properly regulated, can be made accurate, reliable, and impartial and at the same time retain its simplicity, even though the meager directions in the United States Army specifications do not insure uniform results between different operators and at times imposes unjust tests upon some good cements.

Merz, Meyer, Schiffner, Bohme and many others have each pointed out that to determine the time of setting of a cement it should be gauged with a quantity of water proper to it.[17] It has often been demonstrated in this laboratory that 20 per cent of water is not enough to meet the requirements of the fineness, specific gravity, chemical composition, and physical properties of many good Portland cements sufficiently to produce a paste plastic enough to be molded into a pat. The resulting paste is often so dry and non-cohesive that it will not stick together or to the glass plate; and yet 1 to 3 per cent of water in addition will produce the desired plasticity and cohesiveness.

The whole phenomenon of the manufacture of artificial stone from finely powdered cement is one of solution, hydration and subsequent crystallization. The addition of sufficient water is essential for proper solution and hydration. The addition of too much water is to be avoided because of its effect upon the subsequent crystallization, and because the density of the paste must allow of proper manipulation. Therefore, it is very evident that plasticity and not a given percentage of water should be the condition regulating the paste for cement pats.

The insistence of the United States Army engineers upon a paste gauged with 20 per cent of water seems to be a striking illustration of Spalding's assertion that[18] "tests may be imposed which in nearly all cases will secure good material, but often at the expense of rejecting equally good or better material."

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[17] *Soc. Chem. Industry* (1891), **10**, 928.

[18] *Ibid.*, 87.

Merz, Meyer, Schiffner, and others also insist that even when cement is gauged to the proper plasticity there is a large personal error due to the operator himself. After a careful study of this personal error, we have come to the conclusion that it is mainly due to the following five causes:

1. The manner of applying the needles.
2. The presence of small air bubbles near the surface of the pat.
3. The difference in the amount of water brought to the surface in patting the cement together and its presence there in a more or less liquid layer.
4. The difficulty in judging the exact time when the needles cease to make a "visible impression."
5. The difference in plasticity.

To overcome the first difficulty the pat should be made with a flat (not rounded as specified) top as illustrated in fig. 1. The needle should then be applied very gently and after the flat point rests upon the surface of the pat the full weight of the needle should gradually be applied. Failure to hold the needles in an exactly vertical position will often cause the edges to indent where the flat point would not.

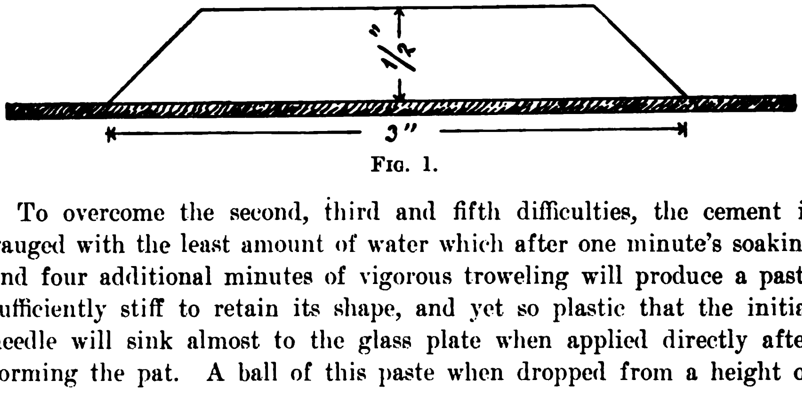

FIG. 1.

To overcome the second, third and fifth difficulties, the cement is gauged with the least amount of water which after one minute's soaking and four additional minutes of vigorous troweling will produce a paste sufficiently stiff to retain its shape, and yet so plastic that the initial needle will sink almost to the glass plate when applied directly after forming the pat. A ball of this paste when dropped from a height of 70 centimeters will flatten very slightly and will not crack. A lump dropped from the point of the trowel will leave the surface of the latter comparatively clean. In forming the pat the cement should be thoroughly patted together with the flat of the trowel. This eliminates the air bubbles near the surface and also brings the excess of water to it. In forming the flat top, the hyperaqueous cement should be wiped off as much as possible with the edge of the trowel, and the surface left smooth and firm.

Difficulty number five is especially marked in slow-setting cements, as sometimes a slight indentation will persist for hours and in the judgment of an individual operator, may even not be fixed within thirty to sixty minutes. However, this uncertainty can be greatly overcome if the needle is carefully applied at intervals of five, ten, fifteen, or twenty minutes according to the rapidity of set, indentations being made in a row. After the pat has become dry, the point where the needle ceases to penetrate is easily recognized (especially so if the surface is slightly moistened), and the time can then be calculated according to the number of previous indentations.

Figs. 2 and 3 illustrate a quick and a normal setting cement, worked according to these directions.

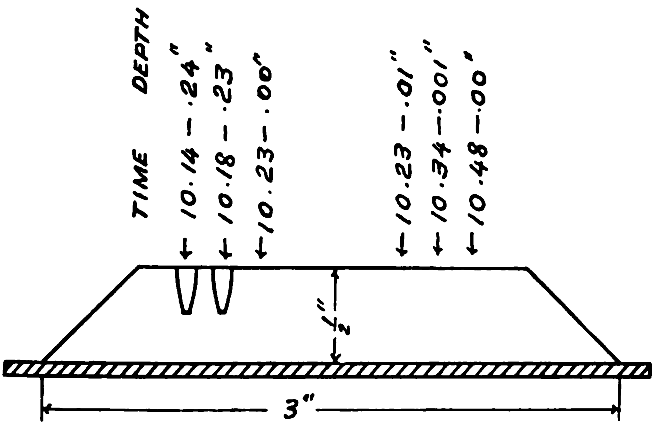

FIG. 2.

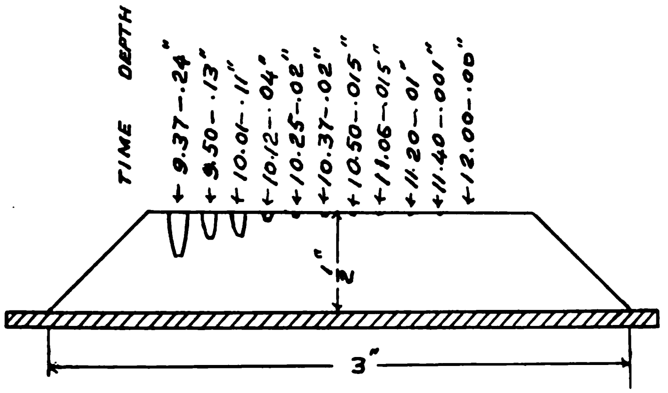

FIG. 3.

This method, once the details are mastered, is just as convenient and quick as a less accurate one. For research work and for cements the setting qualities of which are close to the requirements of specifications, it is especially valuable, as we have found that two pats of the same paste will compare almost exactly, and that even different operators will not vary 10 per cent if they are careful and efficient.

However, it has been our experience that, as Spalding[19] states, "the rate of setting of neat paste gives but little indicaton of what the action may be with sand." Several instances of satisfactory neat and unsatisfactory mortar tensile strength have been encountered in this laboratory, because of the more rapid setting of the cement when combined with sand. It is deemed sufficient to state here that the mortar and neat set must vary because of the differing percentage of water which is used, the difference in physical manipulation, in the air exposure, in mixing, the physical and possibly also the chemical influence of the sand.

For the thorough study of the nature of some cements the determination of neat and mortar setting qualities may be essential. A simple method to determine the setting time of a mortar is here suggested. The beginning of setting when sufficiently rapid appreciably to influence the briquette manipulation is characterized by sudden drying and a slight stiffening of the mortar. If a mixture is made as if for briquettes and the mortar then placed on a glass plate and divided into cubes with the trowel, a slight set may readily be detected when a cube, upon being crushed between the finger and thumb, feels dry, crumbles apart and offers a slight resistance to the crushing force. A harder set may be arbitrarily fixed and determined when the setting has progressed to the extent that a one inch cube dropped from a height of one foot will not crack.

However skilled the operator may be, or however accurate his method, uniform results even by the same operator and on the same cement can not be insured unless the precautions described under the previous headings of "Effects of aëration" and "The moist-air closet" are heeded. Thus, the first sample taken from near the surface of an exposed package not previously mixed, may set in twenty minutes, while succeeding samples taken at a lower depth may not set for hours. When it is desired to make a series of comparative setting tests on the same cement it is advisable to remix the sample thoroughly before weighing and then store the cement in tightly stoppered, wide-mouthed bottles until it is used. The pats should be stored in insulated compartments of the moist-air closet to avoid the influence of the heat liable to be generated by other pats during setting.

SOUNDNESS.

Tests for soundness, like setting pats, should be made with a paste of the correct plasticity. If too little water is used in gauging, the cement will not adhere properly to the plate, and lack of cohesion in the cement itself may result in cracks not due to its subsequent expansion or contraction. If too much water is used, shrinkage cracks of such a nature as to be easily mistaken for evidence of unsoundness, may occur.

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[19] *Ibid.*, 111.

This laboratory uses the same plasticity in its tests for soundness as for setting pats. The cement in this condition is thoroughly wet and pliable, but still stiff enough to retain its shape, therefore it meets all the requirements of a just test. Uniformity between different testers is also secured, because 1 per cent of water more or less would so change the nature of the paste that it would be rendered either too dry or too liquid. The results obtained depend much upon the skill of the operator. Sudden changes in temperature during the steaming and boiling tests should always be avoided. Moistening the surface of the glass plate with a damp cloth before applying the paste will insure better adhesion to the plate. A ball of the paste should then be applied to this surface and patted down very vigorously into the desired shape. Vigorous patting with the flat of the trowel eliminates any interior cracks, reduces the air bubbles to a minimum and brings the excess water to the surface. For soundness, the top of the pat should be arched and the rim troweled to a thin edge as shown in fig. 4. Pats made in this manner will not warp or crack unless the cement is faulty.

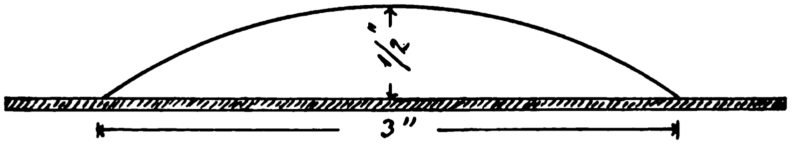

FIG. 4.

We have noticed that different testers interpret the results of soundness tests in different ways. Some operators will report as "unsound" a cement that shows the least trace of warping even after air exposure. Cements showing only slight incipient disintegration are often reported as "disintegrated." In like manner "off plate" and "cracked plate" are often attributed to expansion and contraction. Such an interpretation is unjust to the manufacturer, as warping and cracking to some extent under certain conditions are not to be considered dangerous. A sound pat combined with a broken plate does not necessarily indicate dangerous contraction or expansion. Every cement expands more or less, and in this case the adhesion between the cement and the glass is very strong. As the glass also has an expansion factor, all such cases should be reported as satisfactory if the pat itself shows no sign of cracking or warping. To insure a perfect understanding between the manufacturer, engineer and tester and to avoid unjust or misinterpreted results, specifications should include a descriptive chart of the proper standard interpretation by which the extent, significance, and importance of the various degrees of warping, cracking, disintegrating and shrinking are to be regulated. This laboratory has adopted the standard portrayed and described by Taylor and Thompson [20] in order to insure a complete comprehension in this respect.

Much diversity of opinion exists regarding the rejection of a cement which fails to meet the boiling test,[21] but we regard such a cement as dangerous if it is to be used in works exposed to the heat of the tropical sum.

Excess of lime, coarseness of grinding, insufficient seasoning, and underburning of a cement may cause it to fail to pass the soundness test. If lime is the cause, storage may eliminate the defect, as the free lime would thus be changed to the carbonate, or slaked, and so would not cause subsequent expansion.

Many engineers believe that failure to pass the hot test is not a proof of inferiority, as the cement so failing, if mixed with sand or some other aggregate, has produced durable masonry; it is also a known fact that thoroughly slaked lime paste can be added to a Portland cement mortar without injurious results. We suggest that, as is the case in determining the time of setting, some specification be devised to test the mortar mixture as well as the neat paste.

TENSILE STRENGTH.

The variation in the breaking strength of both neat and sand briquettes is a source of trouble to every cement tester, and despite every effort to eliminate this error, breaks continue to be variable with a persistence that makes it necessary to double or treble the number of briquettes otherwise required. We have made a thorough study of this variation and as a result have come to the conclusion that only a portion of it is due to the personal error of the operator, and that the remainder is caused by the characteristics of the cement itself.

Personal error even with the most careful manipulation, may be produced by (1) unavoidable variation in troweling; (2) difference in the force of the blows; (3) lack of equality in forming each layer of the briquette; (4) variation in the size and shape of the mold; (5) difference in the size and shape of the sand particles; (6) personal error in machine operation; (7) unavoidable internal strains and voids caused by the manipulation which the specifications impose (8) the impossibility of securing a perfectly homogeneous mixture; (9) variation in drying.

The errors caused by the natural characteristics of the cement, and which need more extended explanation, are as follows:

1. It is obvious that it is impossible to expose the same number of cement particles to the action of the air for the same length of time in

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[20] Concrete, Plain and Reinforced. New York (1907). 103-107.

[21] *Loc. cit.*

each instance during troweling; those outside will be exposed more than the inner ones and the evaporation caused by contact with the air may cause setting. We would expect a greater variation from this cause in quick setting cements than in slow ones; and our experience has confirmed this. Slow setting cements give the least variation in tensile strength.

2. Another cause of variation is the tendency possessed by some cements to enclose air bubbles, thus producing irregular voids.

3. Unequal hardening of the exterior and the interior of the cement briquettes may cause differences in heat generated during setting and variable water action during submersion. This cause may also produce internal strains and voids. This variability would also be especially marked in quick setting cements.

4. Irregularity in the intermingling of the crystals during crystallization.

In summarizing the above conditions, only errors which are unavoidable and such as might occur in a batch of four briquettes made and manipulated in the same manner and under the same conditions have been assumed, and our endeavor has therefore been, if possible, to minimize the personal error, and to this end a new type of tamper differing from that specified by the United States Army engineers was adopted. We found it impossible to raise the specified tamper exactly one-half inch at every blow, and at the same time to apply the blow just where we wanted it. A simple, accurate, easily and quickly manipulated tamper which gives the same force to every blow, and hits the exact spot desired, was therefore devised by us.

A (fig. 5) is a thin, hollow cylinder open at *d* and closed at *c*. It weighs about 60 grams. *B* (fig. 7) is a solid brass rod which weighs just 1 pound. The end bearing the lug *b* is inserted into the cylinder *A*, *b* following the groove *a*. To manipulate this instrument, the rod *B* is held near the top with the thumb and forefinger of the right hand, *A* being held in the same way with the left. The lug *b* is drawn hard against the angle in the groove *a*, and the end *c* is placed on the surface of the cement just where it is desired to have the blow strike. The rod is then dropped and at the same time the hold on *A* is loosened. A little practice will enable any one to operate this tamper very quickly, and at the same time to deliver an unvarying blow due to the half-inch drop of the one pound rod. The blows can be directed at will and it is not possible to hit the edges of the mold.

The United States Army specifications direct the tester to raise the tamper one-half inch above the surface of the cement. As the paste and mortar are put into the molds in a lumpy condition, no plane surface line is presented, and as we wished to control the force of each blow as much as possible, a surfacer was devised to enable us to have uniform plane.

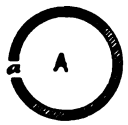

Fig. 6.

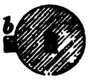

Fig. 8.

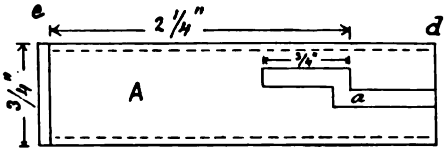

Fig. 5.

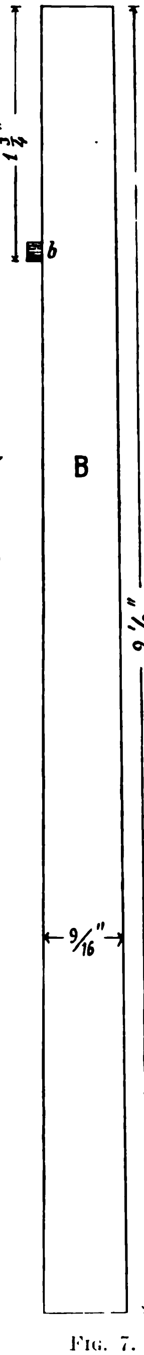

Fig. 7.

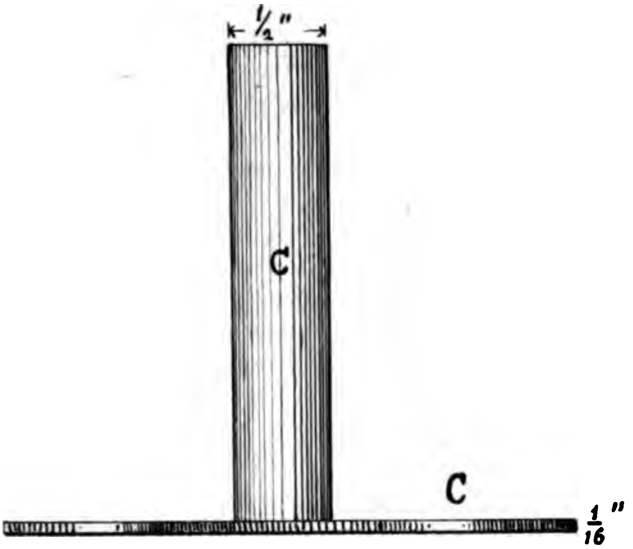

FIG. 9.

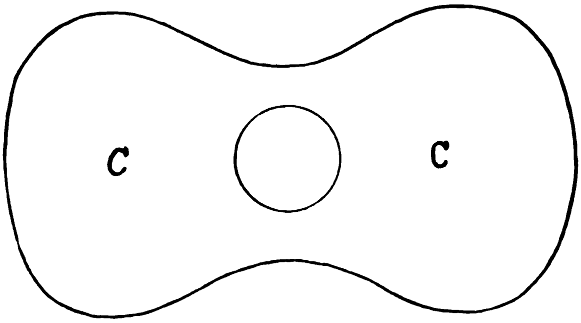

FIG. 10.

This surfacer is made of steel and of the form shown in figs. 9 and 10. The flat surface *c* fits loosely into the mold. The layer of cement is placed into the latter, distributed as evenly as possible with the fingers, and then lightly pressed together with the surfacer. Treating each layer in this manner also keeps the material from sliding and working around during tamping.

To secure uniform effects of tamping it is also essential that the successive layers of each briquette be made as nearly equal as possible. This is easily attained by the use of a small beaker as a measure. After selecting a beaker of the correct capacity it is scooped full of cement, the excess shaken off, and the remainder turned into the mold.

It is not advisable in mortar manipulation to use a measure; the mortar adheres to the glass to some extent and, in dumping, the sand readily falls out, but some cement paste remains attached to the beaker, thus changing the ratio of 1 to 3. We quickly form the mortar into a flat square on the slab, and by pressure with the edge of the trowel rapidly divide it into sixteen cubes. One such cube forms each layer of the briquettes.

In tamping the last layer, it is advisable first to lay an empty mold exactly over the other. The empty mold acts as a guide for the tamper and so avoids the possibility of the loss of the full effect of a blow caused by striking the edge of the mold.

The United States Army specifications direct that each layer of cement in the molds be uniformly tamped with thirty blows. There is no possible way to avoid unequal overlapping of blows with the tamper specified (both round and square). As a result, and also because of the fact that the cement is put into the molds in a more or less lumpy condition, certain voids and excess in the consistency and compactness of the resulting briquettes are unavoidable. Air spaces also form with more or less irregularity. These produce internal strains and variation in cohesion, and consequently differences in the breaks. This illustrates one case of a specification which imposes variability of results upon the tester.

The American Society method eliminates the greater part of this trouble. The paste is more homogeneous and plastic (not lumpy); it is readily pressed into the molds by the fingers and a subsequent patting of the briquette with the flat side of the trowel will eliminate any variation in compactness caused by unequal pressure of the fingers.

The natural tendency in tamping briquettes is to strike the middle, narrow section more than the wider ones; it follows that the resulting briquette is denser in the middle portion. This is the main cause of bad breaks, besides giving a higher result than is just if uniformity of tamping is followed. It is just as essential not to weaken the middle section below the average density. Such a method of tamping will give good breaks, but lower the tensile strength.

After experimenting with many methods to secure as uniform tamping as possible, conducive to good breaks and greatest strength, we have adopted the following method which can be accurately carried out with our automatic tamper.

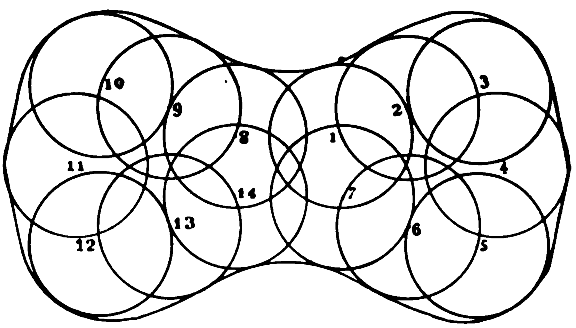

FIG. 11.

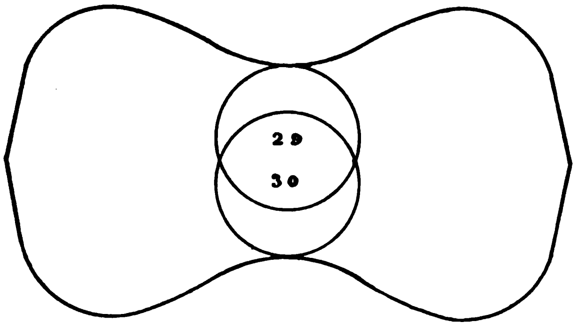

FIG. 12.

The fourteen blows illustrated by fig. 11 are repeated and the final two struck directly across the middle as shown by fig. 12.

Neat briquettes made in this way always break across the center in the Fairbanks roller clips, and seldom vary more than 10 per cent from the highest (5 per cent from the mean). At times, batch after batch will break within a few pounds. Again, at rarer intervals, an occasional break occurs which is 20 per cent or more away from the normal. This variation depends to a great extent upon the nature of the cement and the consistency which the per cent of water used produces. Quick-setting cements give the greatest variation in results.

Sand briquettes still continue to differ considerably, as is true with all other methods. The variation in the size and shape of the sand particles and the corresponding voids and excesses of cement are such that it does not seem possible to contrive any method to eliminate the differences in the tensile strength. The chief value of our system in this respect is that it insures good breaks and hence gives more data to report from. For the purposes of investigation and for work which is under dispute, the question of variation in the force of the blows and their application is eliminated by our method. It is also true that the mechanical tamper renders it possible to depend upon the labor of assistants. The variations in tamping having been eliminated, a smaller number of breaks will suffice. We find that four briquettes from two batches of mortar will almost invariably cover the entire range of possibilities, and show any undue variation in the quality of a series of cement samples, this is illustrated by Table XVIII which shows the uniformity of the cement very plainly, despite the small number of breaks.

TABLE XVIII.—*Showing the uniformity of breaks due to the method of tamping.*[a]

No.	Fineness, specific gravity, and set.[b]						Tensile strength in pounds per square inch.				
	Fineness (100 mesh).	Specific gravity.	Initial set.		Final set.		Neat cement.			1 cement to 3 sand.	
							1 day.	7 days.	28 days.	7 days.	28 days.
			h.	*m.*	*h.*	*m.*					
F2-1	95.9	3.06	1	10	2	15	345	558	625	166	250
F2-2	96.3	3.07	1	15	2	10	331	553	650	164	271
F2-3	96.6	3.07	1	30	2	25	327	495	582	162	274
F2-4	97.0	3.07	1	30	2	25	300	511	568	166	260
F2-5	96.8	3.07	1	30	2	30	322	520	585	159	249
F2-6	96.0	3.07	1	23	2	33	330	528	622	157	245
F2-7	97.0	3.06	1	35	2	45	351	534	562	163	247
F2-8	96.5	3.07	1	37	2	40	334	506	611	163	260
F2-9	96.5	3.06	1	25	2	45	335	503	620	158	249
F2-10	96.4	3.07	1	30	2	50	338	522	600	175	256
Number of briquettes broken							2	3	3	4	4

[a] See also Table XI.

[b] Soundness satisfactory at the end of six and twenty-eight days, respectively.

The following diagram demonstrates the value of our method: Twenty-eight briquettes of cement, ground extremely fine, were made and four briquettes were broken every other day. The results are plotted on the curve shown by diagram number 3.

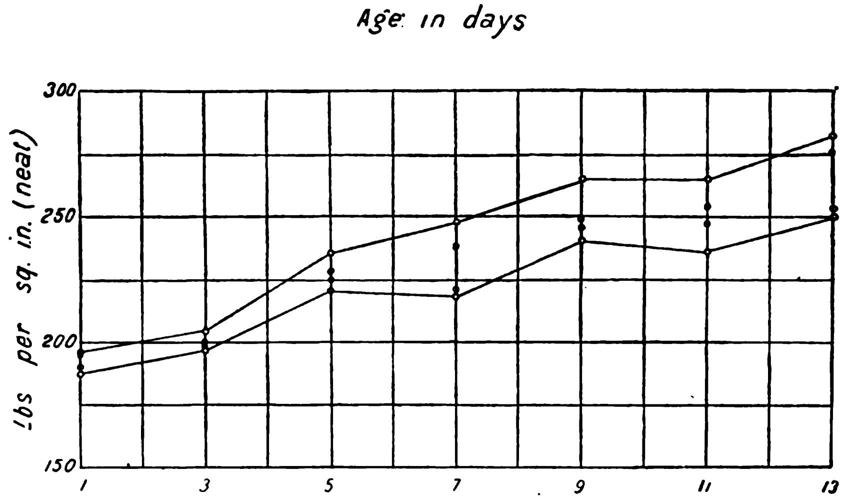

DIAGRAM NO. 3.

This curve is of interest as it plainly demonstrates the unequal action of water upon the briquettes, the tendency being for the curves of the extreme breaks gradually to grow farther apart. The low tensile strength neat, as a characteristic of extremely fine grinding, is also of interest.

In this laboratory all sand briquettes are broken in a German machine (Hugershoff), invented by Michaelis. The Fairbank's roller grips are so heavy and the surface of contact so narrow that they crush through the majority of 7-day mortar briquettes, giving bad breaks and figures representing low tensile strength, and this is especially true of cement which does not in itself develop great strength. The German machine offers a wider surface of contact and the grips support their own weight. Comparative tests carried on for months in routine work give 10 per cent higher results with the latter, but the variation is greater, as the machine is more delicate; the probability of obtaining bad breaks is also greater, but when our system of tamping is used this probability is reduced to a minimum.

It is especially difficult in this climate to obtain uniformity in the demonstration of tensile strength. The laboratory temperature seldom falls below 26°, and is often as high as 31°.5. Our own experiments bear out the conclusions derived from all published data on the influence of temperature. High temperature is conducive to slightly greater tensile strength on 7- and 28-day tests, and also to a greater variation between breaks.

The different tensile strengths secured by different machines, molds, and grips is another reason why there is such a great lack of uniformity between different laboratories. Johnson, Sabin, Thompson and Taylor, Spalding, Butler, and in fact almost every authority on cement testing, devote considerable space to illustrating the variable results that occur from this source. A specification that allows any form of grip and mold can not hope to accomplish its purpose. The Army specifications allow the use of any tensile strength system. The American Society specifications recommend a special form of briquette and regulate certain important factors in the grips. To insist upon a certain machine, grip, and mold would be a rather delicate undertaking, but until this is done there may always be a large difference due to "personal equation" between the tensile strength determinations between different laboratories.

The American Society introduces a very good check upon the mixing and molding of briquettes by specifying that they should be weighed just before immersion and that all which vary more than 3 per cent from the average, should be rejected; in this way greater certainty in results is obtained. It is very easy to work within these limits, and every tester should strive to attain weights which approach each other within 1 per cent. This determination of weight, in addition to being a check upon the uniformity of mixing and molding, may also disclose the effect of unequal drying and of imperfect molds. Sand briquettes are more liable to variation beyond the limits of 2 per cent than are neat. This difference is due, as is the variation in breaking strength, to the lack of uniformity in the size and shape of the sand particles and the irregularity in voids.

The conclusion would naturally be drawn that the greater the density of the briquette, the greater would be its tensile strength. This is not true within limits of 2 per cent, as the other reasons for "personal error" above described may overcome the natural tendency to high tensile strength caused by the density of the material. In sand mixtures, also, a high density may simply show that more sand and less cement have been used.

These facts are illustrated in our routine work and shown by Tables XIX and XX.

TABLE XIX.—*Mortar briquettes, 1 to 3; 12½ per cent water; tamped.*

Sample No.	Time in days.	Tensile strength in pounds per square inch.	Weight in grams.	Sample No.	Time in days.	Tensile strength in pounds per square inch.	Weight in grams.
F1-5	7	171	131.0	F1-8	7	191	131.1
	7	184	129.9		7	177	130.7
	28	214	130.5		28	221	130.0
	28	200	126.5		28	233	129.2
F1-6	7	176	131.4	F1-9	7	188	131.1
	7	192	130.6		7	177	130.5
	28	188	131.0		28	244	131.0
	28	195	130.0		28	232	132.0
F1-7	7	178	128.7	F1-9	7	182	130.0
	7	191	129.3		7	192	130.3
	28	223	128.6		28	238	130.8
	28	216	127.9		28	235	131.0

TABLE XX.—*Neat briquettes made from sample Y1 according to American Society specifications.*

Age in days.	Tensile strength in rounds per square inch.	Weight in grams.	Average weight in grams.	Age in days.	Tensile strength in pounds per square inch.	Weight in grams.	Average weight in grams.
28	603	137.3	137.8	28	636	136.5	136.6
28	665	138.8		28	613	136.6	
28	(539)	138.2		28	599	136.5	
28	638	137.0		28	609	136.8	
28	(686)	137.5	137.9	28	621	137.2	137.0
28	636	137.8		28	(661)	137.7	
28	620	137.8		28	631	137.0	
28	625	138.6		28	617	136.4	

For some time this laboratory was forced to manipulate all cements strictly according to United States Army Engineer specifications, with 20 and 12.5 per cent of water for the neat and mortar tests, respectively. Twenty per cent of water will not satisfy the chemical and physical possibilities of many good Portland cements, and the following table illustrates this fact:

TABLE XXI.—*Variations in tensile strength with varying quantities of water; 7-day results.*

Sample No.	Neat.		1 to 3 mortar, 12.5 per cent water.
	20 per cent water.	22.5 per cent water.	
D4-2	219	633	213
D4-4	182	614	208
D4-6	167	612	216
D4-8	152	600	200
D4-10	178	603	209

The highest results of four good breaks are recorded in each instance.

It will be noticed that the sand briquettes (12.5 per cent water equal to 50 per cent calculated on the cement) present higher results than the neat with 20 per cent of water; and that 2.5 per cent additional for the paste increases its tensile strength over 200 per cent. The following table shows a failure in either case:

TABLE XXII.—*Varying quantities of water used with a failing cement.*

Sample No.	7 days neat.		28 days neat.	
	20 per cent water.	24 per cent water.	20 per cent water.	24 per cent water.
L181	200	404	274	468
L184	257	438	350	523
L186	262	418	318	451

Twenty-seven per cent of water gave lower results than 24 per cent.

It is a simple matter to judge when a cement contains enough water if the method of tamping is used. The surface must be wet when the last layer has been tamped into the mold and of not quite the plasticity described for the pats used in determining the time of setting. A dry surface is positive proof that very low tensile strength will result. The determination of the "normal consistency" can not be used for this purpose as the resulting paste is too slushy for tamping.

If 20 per cent of water gives too dry a mixture, we add an additional quantity sufficient to bring the water to the surface after tamping. The percentage of water necessary to accomplish this result is included with the report of the tests. The results obtained in this way by our tamper and method of tamping are satisfactory, consistent and true to the quality of the cement. The best result of four good breaks is sufficient for all routine work.

The United States Army specifications state that the best results are obtained with a mortar containing 10 to 12.5 per cent of water, and suggest the use of 12.5 per cent. This is contrary to best practice and results. The correct amount of water for sand, as for neat briquettes, depends upon the nature of the cement, and the amount of water necessary to wet the surface of the sand. We find that 12.5 per cent is too much for mortars the neat cement of which worked with 20 per cent makes a fairly wet paste; and that 10 per cent for such a cement gives better results. The reason for this is a physical one, as in tamping a very wet mortar into place, much of the cement is unavoidably lost to the briquettes. During the tamping operation the water is forced to both surfaces, and carries with it the finest (most valuable) cement particles. In finishing the briquette, this top surface, especially rich in cement, is struck off and the resulting briquette is weakened by the reduction of the 1 to 3 ratio as well as by the loss of a portion of its most valuable constituent.

We give this explanation as the reason why many briquette machines fail[22] and why under certain conditions a slight finger pressure will make a stronger briquette than powerful mechanical force. The considerable pressure exerted on the briquettes by such machines forces the water to the surface and this carries cement with it, while the sand is left in the mold.

As the addition or subtraction of as little as 1 per cent of water may effect the resulting strength of a mortar briquette sufficiently to cause the acceptance or rejection of the material, the American Society introduces a good feature in cement testing to cover this effect, for in their specifications the amount of water necessary for any mortar is given according to the percentage of water required to reduce the neat cement to the normal consistency paste. This is shown by the following table:

TABLE XXIII.—*Percentage of water required for standard sand mortars.*

Normal consistency, neat.	1 part cement to 3 parts standard Ottawa sand.
Per cent.	*Per cent.*
22	9.7
23	9.8
24	10.0
25	10.2
26	10.3
27	10.5
28	10.7
29	10.8
30	11.0

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[22] *Eng. News* (1902), 48, 130.

The American Society specifications, with some modifications, will be adopted to test cement for all future Philippine construction work. Although this change has been favored by this laboratory, we do not believe that the above table, regulating the amount of water for mortar briquettes, will be advisable in this climate. A natural, sieved Philippine sand will also be used, but the ratio between the results obtained with this and those with standard Ottawa sand is still to be determined.

Atmospheric influences will not affect the cement during mixing and molding according to these specifications to as great an extent as with the tamping method, as the whole operation of making the briquettes, once the normal consistency has been ascertained, requires only about one-third of the time.

However, the tamping method, according to the United States Army specifications, is more in accordance with actual practice. It takes from sixteen to eighteen minutes to gauge the molds, which is about the average time that concrete manipulation in structural work requires. If the cement begins to set in ten or fifteen minutes, the tensile strength of the briquettes will be reduced by subsequent tamping, which is just what may be expected to happen in field work. According to the American Society manipulation, the briquettes are gauged in five or six minutes, hence the result of quick setting ten or fifteen minutes after the water is added does not affect the tensile strength so much, as the intermingling of crystals which are then formed are not broken up by subsequent tamping. Therefore, failure to pass the initial set requirements of cements tested according to the American Society specifications must be given more important consideration than otherwise, as the tensile strength, while little affected in laboratory tests, may suffer considerably thereby in construction work.

SPECIFIC GRAVITY AND LOSS ON IGNITION.

Much diversity of opinion exists among cement workers regarding the value of the specific-gravity test. It was formerly considered as an almost infallible indicator of adulteration and underburning. The work of Butler,[23] Meade,[24] and of the committee on technical research of the Association of Cement Manufacturers has proved that low specific gravity is often due to seasoning, and that Portland cement can be heavily adulterated and still retain a specific gravity above 3.10. As a result, many engineers do not now attribute any value whatever to this test. However, the experience of this laboratory induces us to support the

[23] *Chem. Eng.* (1907), **5**, 219.
[24] *Chem. Eng.* **6**, 17.

assertion of the paragraph headed "General observations" of the "committee on standard specifications for cement." This committee states:

> "Specific gravity is *useful* in detecting adulterations and underburning. The results of tests of specific gravity *are not* necessarily *conclusive* as an indicator of the quality of a cement, but when in combination with the results of other tests *may* afford valuable indications."[25] (Italics are supplied.)

The specific gravity is *useful* in detecting adulterations because certain adulterations will alter the specific gravity beyond the limits of specifications. However, the adulteration of Portland cement is so readily detected by competent chemists and testers that it is now seldom indulged in by manufacturers. The real problem of cement testing concerns itself with the pure product; and for the valuation of this we find the specific-gravity determination to be a great aid. Of course, its importance is limited. Like the chemical analysis, it gives definite aid only to a limited degree. Chemical analysis will not show the degree of burning nor the compounds that exist in a cement; and the specific gravity will not always disclose adulteration or underburning. However, both these tests give valuable aid in tracing causes of defects which by other tests have been found to exist. For instance, it was the relation between the specific gravity, the tensile strength and the setting time of the cement recorded in diagrams 1 and 2 which gave us the first clue to the cause producing the variations which prevailed throughout these tests and which led us more fully to investigate the effects of aëration on high alumina cements. Now that we understand the nature of this cement, the specific-gravity determination alone enables us to predict very accurately what the results of the other tests will be and to suggest how the cement may be improved.

Failure to pass the soundness tests may be due to two causes—excess of lime or underburning. Unsoundness in conjunction with low specific gravity proves that underburning alone is the cause of the warping and disintegrating.

Cements may attain a low specific gravity as a result of prolonged seasoning. If this benefits the cement, well and good; but if it injures it, then the material should not be allowed to season, or, if seasoning has already developed dangerous properties, it should be rejected. The specific gravity, before and after ignition, will indicate to what extent seasoning has effected a well-burned cement, and a record of tests compared with the corresponding specific gravities will show the quality of the cement developed by the absorption of various amounts of water and carbonic acid.

If a cement shows little change in its specific gravity before and after ignition, and also gives unsatisfactory tests in tensile strength and setting properties, chemical examination will usually show that it has not the proper "hydraulic index."

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[25] Meade, *loc. cit.*

Underburned cements usually have a very low specific gravity, because they absorb water and carbon dioxide more rapidly than well-burned cements and because all the carbonic acid may not be driven off during the burning of the raw material. The compounds formed by underburning are not as stable as those of a well-burned cement and hence are more readily influenced by atmospheric conditions.

Underburning is readily detected by the soundness test provided the cement is "fresh;" but seasoning often eliminates the unsoundness and therefore renders this test of no value for its detection. We must then depend upon the specific gravity, loss on ignition, color, and other tests to disclose the fact. A high loss on ignition is not characteristic of the best brand of Portland cement, even after prolonged storage.

R. & W. Fresenius[26] consider "that the limiting value of the loss on ignition of good Portland cement should not exceed 3.4 per cent."

The following table illustrates this contention:

Conditions.	Cement A.		Cement B.		Cement C.	
	Specific gravity.	Loss on ignition.	Specific gravity.	Loss on ignition.	Specific gravity.	Loss on ignition.
Not quite fritted	2.92	3.59	3.04	1.47	2.92	5.39
Slightly fritted	3.105	0.66	3.15	0.59		
Strongly fritted	3.115	0.27	3.18	0.19	3.00	2.36
Very strongly fritted					3.19	0.24
Overburned	3.05	0.65	3.05	0.28		

Sabin[27] remarks "that the determination of water and CO_2 may give some idea of the deterioration of a cement on storage. M. Candlot considers that in the case of Portland cement a loss on ignition (water and CO_2) exceeding 3 per cent indicates that the cement has undergone sufficient alteration appreciably to diminish its strength. Spalding[28] affirms that "if the quantity of CO_2 be large, it indicates either that the burning has been incomplete or that the lime has become carbonated by subsequent exposure. The energy of the lime is thus diminished, the portion of lime in combination with CO_2 being inert."

While we have not enough data to cover every instance and to formulate this as a general rule, it has been our experience that the absorption of carbonic acid and water decreases the tensile strength of every *sound*

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[26] *Soc. Chem. Industry* (1894), 13, 252. *Ztschr. Anal. Chem.* (1893), 32, 433, 445.

[27] Sabin, Louis Carlton: *Ibid.*, 34.

[28] *Ibid.*, 4.

Portland cement, even though it does not develop quick-setting properties by this exposure. Table XXIV gives a typical example:

TABLE XXIV.—*January 22, 1907—mortar, 1 to 3.*

[Specific gravity, 3.11.]

	7-day.	28-day.	Number of briquettes broken.
Average	171	227	12
Highest	195	250	12

This same cement stored in coarse canvas cloth bags, twenty days and three months longer, gave the following results:

[Specific gravity, 3.03 after 3 months.]

	7-day.	28-day.	Number of briquettes broken.
After 20 days:			
Average	147	212	12
Highest	165	230	12
After 3 months:			
Average	135	200	16
Highest	146	211	16

From the nature of things this loss in tensile strength is not difficult to explain. It is generally understood that all cements are improved by storage, but it has been proved that this is only true of those cements which are either too high in lime or underburned. Aëration renders part of the excess or free lime inert because of the formation of the carbonate of calcium and also slakes some of it by the absorption of water. Thus, the cause of unsoundness is removed in time, and the cement is gradually improved in this respect. But "the higher in lime a cement is the greater its strength is known to be if thoroughly burned,"[29] and "the maximum of lime is usually controlled by the soundness tests."[30] Therefore, if a cement is sound it does not contain excess or free lime and the carbonization of the lime in a sound cement should reduce its tensile strength, as it lowers the percentage of *active* lime, the carbonate of calcium being inert.

With all due respect for the great value of Meade's work, we take exception to a portion of his assertions relative to the specific gravity.

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[29] *Eng. News* (1905), **53**, 84.

[30] *Chem. Eng.* (1907), **5**, 343.

Among other conclusions he states [31] "that low specific gravity is usually caused by seasoning of the cement or of the clinker, either of which improves the product. * * * Underburned cement is readily and promptly detected by the soundness tests and no others are needed for this purpose. * * * That the requirements of specific gravity should be omitted."

Underburning is readily detected by the soundness test, only when the cement is fresh. Seasoning of underburned cement may eliminate the causes of its unsoundness. Meade himself states in this same reference that an underburned cement which, when freshly made, failed to stand a 5-hour steam test without complete disintegration, after one month's seasoning stood 5-hour steam and boiling tests perfectly. The greater part of the cement received at this laboratory for commercial testing has been seasoned for a greater or less length of time, therefore the soundness tests are not liable to detect underburning in most instances.

Cement raw material, high in alumina, fuses so readily that it is difficult to control its burning, and as a result almost all high alumina cements vary considerably. It is also very difficult to detect the relative degrees of burning which the commercial, high-alumina cements have undergone and it is only possible to do so by taking into consideration many of the physical properties of the material. It has been observed that a brown shade,[32] a low specific gravity,[33] a high loss on ignition, the presence of blotches [34] between the soundness pat and the glass plate, a high, insoluble residue and a generally erratic behavior of a cement, exist simultaneously with a relative increase in the rate of carbonic acid and water absorption. These are all regarded as signs of underburning, and a study of all of them gives the only indications of the relative degree of burning of seasoned, high-alumina cements that we have been able to recognize.

Meade's statement that seasoning of the clinker improves a cement is also open to discussion. Some cements are improved by this procedure, but many others are not. Instances are on record where seasoning induced quick setting and low tensile strength, even when calcium sulphate was present. Meade admits "that cements should contain at least 2.5 times as much silica as alumina. Cements containing less than this amount of silica are apt to be quick setting, or else to become quick setting on exposure to air."

It is hardly necessary to state that we do not think that the requirements of specific gravity should be omitted from specifications. This test is of great value under certain conditions. Every good Portland cement will meet its requirements before or after ignition, and therefore its determination imposes no unjust or partial test.

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[31] *Ibid.*, 6, 19.

[32] Sabin, Louis Carlton: *Ibid.*, 36.

[33] *Soc. Chem. Industry* (1894), **13**, 255.

[34] Taylor and Thompson: *Ibid.*, 101-107.

Determination of the specific gravity will be valueless unless the effects of aëration are guarded against, as the exposure of the small quantity of cement necessary for this test enables the action of the atmosphere to alter its composition very much in a short time and so to reduce its specific gravity accordingly.

It is the practice of this laboratory to take the cement for the specific gravity determination from the sample at the same time that the material for the other tests is taken. It is then dried at 110° for thirty minutes and immediately put into small, glass bottles which are tightly corked until the cement has cooled; it is only used after this procedure.

The difference between the specific gravities before and after ignition indicates the amount of volatile constituents present in the cement, but when it is desired to know only the amount of carbonic acid and combined water which has been absorbed, the loss on ignition affords a much simpler and a more accurate test.

CLIMATIC INFLUENCES.

Local, tropical, climatic conditions must necessarily have an influence upon cement and cement testing. In the tropics, all work is done practically in the open air, being protected only from the direct rays of the sun. The climatic conditions under which cement tests or commercial work are undertaken coincide very closely with the meteorologic observations which are given in the following table for the year:

TABLE XXVI.—*Summary of meteorologic observations taken at Manila,*[a] *P. I., situated on the west coast of the Island of Luzon.*

Month.	Temperature.						Mean relative humidity.	Average rainfall.	Average number of rainy days.	Mean cloudiness.
	Mean.		Maximum.		Minimum.					
	°C.	°F.	°C.	°F.	°C.	°F.	*Per ct.*	*In.*		*Per ct.*
January	25	77	33.9	93	16.7	62	78	1.19	5	4.6
February	25.5	78	35.6	96	16.1	61	74	.41	3	3.8
March	26.6	80	35.6	96	17.2	63	72	.74	3	3.8
April	26.3	83	37.2	99	18.9	66	71	1.14	4	3.5
May	26.3	83	37.8	100	21.7	71	77	4.20	9	5.1
June	27.8	82	36.1	97	21.7	71	82	9.62	16	6.8
July	27.2	81	35	95	21.1	70	85	14.57	21	7.5
August	27.2	81	34.4	94	20.6	69	84	13.87	20	7.5
September	26.6	80	34.4	94	21.1	70	86	14.93	20	7.4
October	26.6	80	35	95	20.6	69	83	7.54	16	6.1
November	26.1	79	33.3	92	18.3	65	82	5.13	12	5.8
December	25	77	33.3	92	15.6	60	81	2.13	8	5.6

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[a] "The climate of Manila is hot and moist during the greater part of the year. During the spring months it is dry. The afternoon temperature of the hottest portion of the year is modified by the northeast trade winds that prevail at that season." Brewer, Isaac W.: Personal Hygiene in Tropical and Semi-Tropical Countries (1908), 119.

All the requirements of standard American cement specifications are based upon cement action characteristic of a colder climate. It would be possible, of course, to manipulate the cement testing itself in tropical countries at the temperature limits specified in American standards; but this could only be done at great inconvenience and at a large expense and furthermore it would not be practical, as the results of tests so conducted would not be true criteria of the behavior and value of the cement when used in construction work. The allowances and requirements due to the effect of the relative difference in temperature between temperate and tropical climates should therefore be taken into account in local cement specifications.

During the past year this laboratory has received a number of letters upon this subject from manufacturers, engineers, contractors, testers and other cement workers. These either request information or make statements regarding the influence of local climatic conditions upon various phases of cement action and manipulation. A diversity of opinion has been expressed in regard to the effect of these influences by men familiar with cement work, and probably this is due to the fact that Portland cement is a very variable product and therefore local conditions which would improve the quality of one brand would injure another, and vice versa, and during the past year our endeavor has been to secure a sufficient number of results with various brands of cement to throw some light on the effect produced by this climate on the tests.

Careful cement testing with due consideration of all conditions is of the greatest importance in a country such as this, where much of the material comes a long distance by sea, and where the rejection of a shipment means a proportionately greater loss to the dealer, owing to the cost of transportation, and also to the engineer, as construction work may be delayed. On the other hand, construction work is very expensive in this Archipelago and therefore a rigid interpretation of specifications is necessary to provide against all possibility of the use of dangerous cement.

Contrary to the general belief, the difference between local climatic conditions and those of the temperate climates exerts very little influence upon the usual standard Portland cement tests themselves. Provided the cement is of good quality the warmer temperature prevailing here usually tends to give higher results. Of course, the fineness is not affected by it, and the specific-gravity determination is made independently of the surrounding temperature. The "accelerated soundness" tests especially, are benefited, as the cement does not suffer as great a change in temperature; and hence expansion and warping is not so marked. Climatic conditions improve the characteristics of early tensile strength of most cements, as the variation in temperature from day to day and from hour to hour is only slight, the temperature of the water bath is higher than in cold climates, and the temperature during gauging is also higher; these are all factors conducive to the development of high early strength.[35] Comparative tests of both sand and neat briquettes made and preserved in the cold-storage room (17° to 21° C.) and also in the laboratory (26° to 30° C.) gave almost without exception lower results, from 3 to 10 per cent, at the lower temperature. The briquettes broke more uniformly when made at the colder temperature. The difference between the strength developed under both conditions was always slight and within the limits of personal error.

However, the relatively high temperature of this climate will seriously effect the setting properties of some Portland cements. This is illustrated by Tables XV and XVI (pp. 152 and 153). Fortunately, the setting properties of the majority of cements are only slightly influenced by this difference in temperature (Tables XIV and XVII). It is the experience of this laboratory that high alumina cements develop setting qualities characteristic of class 2 (Tables XV and XVI); further experimented work is necessary to determine whether this phenomenon holds true only with this class. When comparatively fresh, high-alumina cements set slowly at both temperatures (Table XIV), additional seasoning renders them slow setting at first at 17° to 21°, but quick setting at 29° to 31°, and finally quick setting at both temperatures.

The development of quick setting is marked by other peculiar characteristics. When the absorption of carbonic acid and combined water has progressed sufficiently, no practical amount of water which can be added will retard the rapidity of setting or eliminate the early generation of much heat, but in the earlier stages of seasoning a variation of as little as 0.5 per cent of water in mixing may produce a most remarkable difference in the time of the initial and final sets. This is shown by the following table:[36]

TABLE XXV.—*Showing the effect of varying amounts of water on the time of setting.*

Sample No.	Water.	Condition.	Initial set.		Final set.	
	Per cent.		*h.*	*m.*	*h.*	*m.*
F5-1	21	Becomes dry and noncohesive; heats up 6° in 4 minutes	([a])		([a])	
F5-1	22	Just plastic enough to mold	0	15	1	10
F5-1	23	Plastic	1	10	2	25
F5-3	22	Just plastic		20	1	10
F5-3	23	Plastic	1	30	2	25
F5-5	22.5	do		15		30
F5-5	23	do	1	15	2	20

[a] Impossible.

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[35] *Annual Report Chief of Engineers, U. S. A.* (1894), 234. Sabin, Louis Carlton: Cement and Concrete. New York (1905), 119–120. Alexandre, Paul: Recherches Experimentales sur les Mortiers Hydrauliques.

[36] See also Table XVII of this paper.

The samples were well mixed and screened before testing; troweling was done as uniformly as possible for exactly five minutes; the atmospheric and moist-closet exposure was the same in all cases, except that there was a gradual change in temperature from 27° at 8 a. m. to 29° at 2 p. m.

After troweling sample F5-1 with 21 per cent of water for about four minutes, it suddenly became hot and dry, crumbling apart. No amount of patting would cause the cement to stick together sufficiently to form a pat.

The same result was observed on repeating the operation, and a thermometer placed in the mass rose 6° in four minutes. However, upon adding 22 per cent of water to the same cement no rise in temperature was observed during troweling; the resulting paste was sufficiently plastic to be easily molded into a pat; and the needle used for the initial set when first applied, sank about one-eighth of an inch. However, five minutes after the pat was placed in the moist-air closet, it began to heat and to dry slightly, the initial set taking place in fifteen minutes. This experiment was repeated with similar results. Twenty-three per cent of water was then used. The plastic paste, when formed into a pat, acted normally in every way and gave a satisfactory setting time.

The results obtained with sample F5-3 and F5-5 were practically identical. In the case of the latter, the excess percentage of water was reduced by 0.5 per cent to determine if possible the minimum quantity necessary to effect so profound a change.

Two important facts become evident from the above data, namely, that both the plasticity and setting time of a cement, such as was being tested, are much affected after a certain quantity of water has been added by the subsequent addition of even very small amounts of the solvent.[37]

We are not prepared to discuss fully these results at the present time, but their analogy to the phenomenon of the crystallization of certain salts from solution is striking. Many salts have a critical solution factor. Under slow evaporation they will remain in solution until a certain limiting percentage of the solvent has been reached, when the salt will crystallize almost instantly, heat being generated during the separation. A cement, the setting properties of which are so profoundly affected by the addition of even small quantities of water, may be said to have a critical solution (or hydration) point. We would hesitate to decide whether such a cement deserves to be approved. If tested according to the United States Army specifications it would fail to pass the setting test, but under those of the American Society the normal plasticity method will give it sufficient water to cause it to set slowly.

An engineer in these Islands related an experience illustrating the practical importance of this problem. The mortar, after mixing, was dumped into a car and transported to its destination by rail in five minutes. Working with a large shipment of this cement no difficulty was experienced for some time, but finally when one carload reached its destination the cement had set so hard that it was removed from the car only with much difficulty. He attributed this change to the variability of the cement, but we are inclined to believe that the water added was just sufficient to bring the cement to the critical solution or hydration point and that a bucket or so of water less than was usually employed, was used in mixing, and quick setting was the result.

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[37] This same phenomenon is less delicately shown in fig. 19 of Taylor and Thompson "Concrete, Plain and Reinforced." It will be noticed that Portland cement *C* (without gypsum) reached its final set even in less than thirty minutes with 20 per cent of water. With 25 per cent of water the initial set took one hour and thirty minutes and the final set five hours.

Portland cement is most affected by local climatic conditions before and not after it is gauged. High temperature and the alternating humid and dry atmosphere are conditions under which hydration and carbonization are accelerated. In consequence, the majority of commercial products must be especially prepared to withstand tropical climates. Portland cement is very susceptible to changes under these conditions, and it is therefore essential to the best practice that cement intended for use in the tropics should develop no dangerous properties by the absorption of water and carbonic acid in normal quantities. The cement problem of tropical countries depends for its solution upon the characteristics of Portland cement; and our efforts have been to determine what class of cements are least injuriously affected by exposure and seasoning.

We believe that high-alumina cements are least efficient for use in tropical climates, although they have one laudable feature in that they never show the slightest inclination toward warping or disintegrating. Air, steam and boiling tests always develop perfect soundness. This is probably due to the fact that aluminous raw material fuses very readily at a comparatively low heat. "Lime burned at a high heat slakes much more slowly, and is therefore more likely to be injurious than when burned at a low temperature." [38]

> Aluminous cements gain most of their strength very quickly. "The aluminates are thought to contribute little to the final strength of the mortar, as they are not permanent compounds, but are acted upon by various salts with which they are likely to come in contact in the work. For this reason they are not adapted for work exposed to the action of air and sea water." [39] "The aluminate acts in a very energetic manner upon the set, but very little upon the hardening which is caused by the silicate of lime." [40] Also "from the character of the silicates and the aluminates it is evident that the latter are acted upon more quickly and rapidly than the silicates, and it is to the crystallization of the lime from the aluminates that the initial set must be contributed. Subsequent hardening must be due to the liberation of lime from the silicates." [41]

In conformity with these quotations, it has been our experience with cements of this nature that the 7- to 28-day gain is small; that satisfactory 7-day breaks do not insure satisfactory 28-day strength; that 7-day strength may be even greater than 28-day; that little gain in strength takes place after twenty-eight days and instances are on record where the strength of the briquettes weakened after three months. The fifty samples illustrated in diagrams numbered 1 and 2 show only an average gain (seven to twenty-eight days) by the testers, of 16.45 per cent for neat and 48.9 per cent for sand briquettes, whereas the increase desired by the Army specifications is at least 20 and 57 per cent, respectively (Table I). "Cement giving high early strength is to be relied upon only in so far as it has been shown by experience that it is capable of maintaining such strength." [42]

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[38] Spalding, Frederick C.: *Ibid.*, 73.

[39] *Ibid.*, 54.

[40] *Ibid.*, 58.

[41] Clifford, Richardson: *Eng. News* (1905), 53, 984.

The fact that the early strength of this class of cement can not always be relied upon is probably due to its nonuniformity in burning. Owing to the fusibility of the calcium aluminate, which causes balling-up and sticking together in the hot zone of the kiln,[43] thus preventing uniform burning, cements high in alumina are apt to be very erratic in the stability of their compounds. As a result the rapidity with which they unite with water and carbonic acid when exposed to the atmosphere varies. The relative rapidity of the absorption of carbon dioxide and water by cements under similar conditions would therefore indicate the relative degree of low burning.

The most important characteristic of a high-alumina cement and the one that needs the most consideration is its susceptibility to become quick setting by exposure to the air. It has been our universal experience that Portland cements of this class containing more than 8.5 per cent of alumina always gave satisfactory results if they are tested before they have combined with more than 2 per cent of water and carbonic acid; and that when they had combined with more than 3 per cent of volatile constituents they failed to meet the setting and tensile strength requirements.

It would seem as if there is something radically wrong with a cement that will not withstand atmospheric exposure to such a slight extent without developing dangerous properties, and such a cement should be rejected for use, especially in this climate. A typical example, sample No. 8 as recorded in Tables VII and VIII, will suffice to illustrate this.

It is difficult perhaps to realize why such a slight difference in volatile constituents should so change the quality of a cement; and that the same cement which at first set in one hour and thirty minutes (loss on ignition=2.63 per cent) should, after a little more aëration develop such rapid setting properties, and set in twenty-three minutes (loss on ignition=3.92 per cent).

The combination of Portland cement with water and carbonic acid absorbed from the air is represented for all purposes of discussion by the quantity of water necessary to slake the lime, if all were present as calcium oxide, and to combine with the slaked lime to form calcium carbonate, regardless of any intermediate reaction on other compounds which might be present. This change can therefore be represented by the following equations:

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[42] Spalding, Frederick P.: *Ibid.*, 88.

[43] Meade: *Chem. Eng.* (1907), 5, 345.

$$CaO+H_2O=Ca(OH)_2$$
$$Ca(OH)_2+CO_2=CaCO_3+H_2O$$

or,

$$CaO+CO_2=CaCO_3$$

and therefore, 1 part by weight of water will unite with 3.1 parts of lime to form 4.1 parts of slaked lime, and one part of carbon dioxide will unite with 1.5 parts of lime to form 2.27 parts of calcium carbonate.

From the above equations it is very apparent how an otherwise unsound cement is improved by the absorption of 3 or 4 per cent of water and carbonic acid. Excess of free lime causes the unsoundness and the more of this lime which is slaked or rendered inert before gauging the cement, the sounder the resulting product will be. The calcium silicates being much more stable compounds than the calcium aluminates, the latter would be acted upon first by climatic influences. The addition of lime or slaked lime to a cement retards the setting, and from the nature of the reaction, quicklime would retard the setting more than slaked lime. The natural tendency then of the lime is to off-set the quick setting properties of the aluminates. Other conditions being the same, anything which tends to reduce the activity of the lime in a slow-setting, sound cement, will increase the rate of its setting. The ignited cement of sample No. 8 had the following composition:

	Per cent.
Silica (SiO_2)	20.5
Alumina (Al_2O_3)	8.6
Iron oxide (Fe_2O_3)	2.8
Lime (CaO)	65.4
Magnesia (MgO)	2.3
Sulphuric acid (SO_3)	0.4

Table VIII shows that the cement from the bag had absorbed 0.50 per cent more carbonic acid and 0.79 per cent more combined water than that in the can. It therefore contained (equation 3) 1.13 more inert calcium carbonate and 3.24 per cent (equation 1) more slaked lime; or 0.75 per cent (equation 3) of the lime present in the raw material had been rendered inert, and 2.45 per cent had been slaked by the additional absorption of combined water and carbonic acid by the same cement stored in the bag.

The lime in combination with silica must be left out of this consideration as the silicates of calcium exert practically no influence upon the initial setting properties of the cement. The entire loss in active lime affected the equilibrium maintained in the early setting properties by the opposing forces of the aluminates and the lime not in combination with silica. Therefore, a loss in the activity of this lime representing 0.75 per cent of the total cement of sample number 8 affects this equilibrium to a degree many times greater than if the silicates would need to be taken into consideration.

Synthetic experiments also show this same phenomenon. "If much more than 10 per cent alumina is present the cement is almost sure to be quick setting even with the addition of sulphates."[44] "When cement treated with sulphate of lime has regained quick set, it may again be made slow set by addition of a small quantity of lime."[45]

Our belief that this cement is not of good quality is also supported by universal experience. We have already stated that this class of cements gives satisfactory tests when the samples are comparatively fresh, but fails to do so after seasoning. It will be noted that the percentage of alumina and silica in sample number 8 satisfies the limits of R. K. Meade's formula for "freshly made American Portland cements which pass standard specifications for soundness, setting time, and tensile strength,"[46] namely:

	Per cent.
Silica	20–24
Alumina	5– 9
Iron oxide	2– 4
Lime	60–63.5
Sulphur trioxide	1– 2

However, they do not fall within the limits of Le Chatelier's formula for "the limits of the amount of material usually present in good commercial (therefore seasoned) Portland cement,[47] that is:

	Per cent.
Silica	21.0–24
Alumina	6 – 8
Iron oxide	2 – 4
Lime	60 –65
Magnesia	0.5– 2
Sulphur trioxide	0.5– 1.5
Water and carbonic acid	1 – 3

The percentage of sulphur trioxide is also lower than that given by both authors; and the loss on ignition is greater than that given by the formula which considers it.

Furthermore, Meade states that "cements should contain *at least* 2.5 times as much silica as alumina. Cements containing less than this amount are apt to be quick setting or else to become quick setting on exposure to air." Sample number 8 contained 2.38 times as much silica as alumina, and its actions supports Meade's conclusion.

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[44] Meade: *Chem. Eng.* (1907), 5, 345.

[45] *Ibid.*, 349.

[46] *The Chem. Eng.* (1907), 5, 349.

[47] *Trans. Am. Inst. Min. Eng.* (1893).

Cements which contain less alumina and more silica than sample number 8 withstand exposure much better. All of the five different cements recorded in Table XXVI below, failed in setting time and tensile strength when their seasoning had progressed as indicated by the "loss on ignition" column. However, number 5 withstood aëration the best. It was only after it had stood exposed to the air for a very long time and had united with 6.36 per cent of water and carbonic acid that it failed.

TABLE XXVI.

Constituent.	Cement 1.	Cement 2.	Cement 3.	Cement 4.	Cement 5.	Cement 5, ignited.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Silica (SiO_2)	20.65	20.70	22.0	20.52	21.28	22.9
Alumina (Al_2O_3)	8.57	8.42	8.9	8.71	6.95	7.5
Iron oxide (Fe_2O_3)	3.07	3.01	3.0	2.65	2.29	2.5
Lime (CaO)	61.83	61.60	59.9	61.30	61.08	65.7
Magnesia (MgO)	2.26	1.94	1.55	1.96	0.21	0.2
Moisture (110°)	0.41	0.34	----------	0.88	0.72	----------
Loss on ignition (water and carbonic acid).	2.47	2.76	5.3	4.33	6.36	----------
Sulphuric acid (SO_3)	0.51	0.59	----------	0.46	1.17	1.26
Carbonic acid (CO_2)	0.78	0.43	----------	3.04	4.36	----------

Seven and 28 day mortar briquettes (1 to 3), as the seasoning of the cement progressed, gave the following tests of tensile strength:

7-day.	28-day.	Loss on ignition.
		Per cent.
236	320	2.97
187	247	4.53
172	211	6.36

Contrary to this behavior, number 4 gave the worst results and a very plastic paste made from it set in fifteen minutes with a rise in temperature from 29° to 38°.5 C. Cements numbered 1 and 2 showed only 2.47 and 2.76 per cent loss on ignition respectively and yet they were quick setting.

By further investigations of this nature we hope to prove what brands of Portland cement in particular are best suited to withstand tropical climatic influences best. At present we feel justified in drawing the following conclusions as being conducive to the best results and practice for all cement operations in this and similar regions.

CONCLUSIONS.

1. We believe that the composition of Portland cement best adapted for use in tropical climate should be within the following limits:

	Per cent.
Silica	22 -24
Alumina	5 - 7
Lime	62 -65
Magnesia	0.0- 4
Sulphur trioxide	1.0- 2
Water and carbonic acid	0.5- 3

2. "Soundness" in accelerated tests deserve special attention here, because of the prevailing high temperature. Perfect soundness is especially important for concrete works which are exposed to the intense heat of a tropical sun.

3. "Underburning" is fatal to the efficiency of Portland cement to be used in the Tropics, as the unstable compounds so formed are most easily attacked and decomposed by the energetic atmospheric influences.

4. All "sound" cements should be protected from additional aëration as much as is practicable, as otherwise quick setting or low tensile strength is liable to be developed.

5. Sound and well-burned cements, high in silica and low in alumina, will withstand climatic influences best both before and after gauging.

6. High alumina cements give fairly satisfactory results if they are used before they develop quick setting. Quick setting is sure to develop in such cements if they are exposed to the air for any considerable length of time.

7. Samples sent to the testing laboratory should be preserved in packages which thoroughly protect the cement from the atmosphere. No accurate results consistent with the quality of the cement as it exists in the barrel at the time of sampling will otherwise be possible. Setting tests made at the laboratory before and after exposure should be insisted upon, and if quick setting develops by this additional seasoning the cement should be rejected.

This work will be continued and our effort will be to secure samples of as many grades of cement as is possible, in order more thoroughly to test the soundness of these conclusions.

EDITORIAL.

PERIDINIUM.

For a number of years the Bureau of Health has received many complaints from the residents of Bataan Province to the effect that the dumpings from the sanitary barge *Pluto* caused a great mortality among the fish along the shores of that province. An investigation into the matter, conducted by Deputy Commissioner H. M. Smith of the United States Fish Commission steamer *Albatross*, proved that the mortality among fish is in no way connected with the *Pluto* but is due to visitations of *Peridinium* in Manila Bay. The following is taken from a report on this subject by Dr. Smith:

There have been at least three visitations of *Peridinium* in Manila Bay during the current year, a noteworthy one occurring in the latter part of January. The discoloration of the water at that time was observed about the 23d of the month, and increased in intensity until the 26th or 27th, after which it rapidly diminished and practically disappeared from the head of the bay by the 31st. Another visitation was observed during the third week in March but was less extensive than the foregoing.

Whenever *Peridinium* has invaded Manila Bay, the water over large areas has been made turbid by minute protozoa, and at a distance has the peculiar pale reddish color characteristic of such invasions. When the water was viewed over the side of the *Albatross*, another color was seen; and a very pronounced iron-rust tinge was observed when the animals were closely packed. The rusty color was found to be due to contained chlorophyl. At times, dense masses of *Peridinium* floated past the *Albatross* in wavy bands several yards wide and hundreds of feet long.

During the prevalence of these invasions, the bay is unusually phosphorescent, and tests show that the *Peridinium* is the chief cause of the luminosity. A tumblerful of water taken at night alongside the *Albatross*, and found to be thick with the organisms to the exclusion of all other creatures, glowed brightly with a blue light when carried to a dark room and agitated.

Whenever *Peridinium* has appeared in the bay, there has been a remarkable scarcity of other forms of animal life. The dense schools of small fish (*Atherina* and others) which are nearly always present in the surface waters of the bay, and are so conspicuous about the wharves and vessels, disappear completely, and with them the larger fishes that prey thereon. For a number of days not a living thing of microscopic size can be seen at the surface of the water, and fish-eating birds also disappear. As the amount of *Peridinium* diminished, the small fishes gradually reappear in the open waters (coming either from the bottom or from places where streams enter the bay and render the water unsuitable for the protozoän). The gulls and terns also return. Finally, when the creatures have practically withdrawn, the small fish reappear in myriads.

A small, salt-water aquarium on the *Albatross,* containing a number of different kinds of fishes and mollusks from points south of Manila, was in a very flourishing condition when the ship entered the bay one morning several weeks ago, but the same night nearly all the fishes and mollusks were killed, and examination showed myriads of the *Peridinium* on the gills, etc. The few fishes that survived were rapidly succumbing, until the water supplying the aquarium was strained through a fine-meshed bolting cloth, thus eliminating the injurious organisms. Since then the fishes have been quite healthy.

During the prevalence of this pest, the Manila markets contain much less fish than normally, and many stalls are entirely vacant. Inquiries among the fishermen show that there is a decided falling off in the catch and that some dead fish are reported in the *baclods.* The injury done to the fish, however, appears to be much less than might be expected, the known mortality among aquatic creatures being so small as to afford a noteworthy contrast to the ravages of *Peridinium* in America and Japan.

AN ACCOUNT OF A HUMAN SACRIFICE HELD BY THE BAGOBOS, DISTRICT OF DAVAO, MINDANAO, P. I.

A geological reconnaissance of the Island of Mindanao and the Sulu Group was begun by the division of mines of this Bureau in September, 1907. The scientific work was under the direction of W. D. Smith; the military escort which was necessary throughout most of the work was commanded by Lieut. Charles S. Caffery, Second Infantry, United States Army. One part of this work consisted in an expedition from Kotabato to Davao, a distance of over 200 miles, 90 of which were covered by a sternwheel boat plying up the Rio Grande, or Pulangi, River, from where the party traveled overland across the Matutan and Apo Ranges to Davao Gulf. This party formed the second expedition of white men to make this entire trip.

The region west of the divide is inhabited by Moros, Mohammedan tribes in a semipacified state, and Manobos and several other pagan groups live in the region on the east of the divide. Several tribes or subtribes are to be found on the slopes of Mount Apo, among which may be mentioned the Atas, Giangas, Bagobos and tne Kalagans. Several Americans and Spaniards have visited the people around Davao Gulf and have studied their ethnology. The Jesuits devoted themselves for many years to missionary work in Mindanao and much of scientific value was accomplished by this learned and able body of men. Mr. Frederick Sawyer has gleaned more or less scattered information from their "letters" which he has included in his book "The Inhabitants of the Philippines,"[1] in which he merely refers to human sacrifices without giving any of the details, and these references are to sacrifices held only among the Giangas and Tagakaolos. Blumentritt[2] says even less about the Bagobos, and furthermore, he never saw any of the people of the Philippines about whom he wrote. No work has yet been carried on among these peoples by the division of ethnology of this Bureau and as it may be some time before any attempt will be made to study them, I have obtained permission from the chief of that division to contribute some interesting data regarding some of their customs.

We encountered Bagobos along the route for several days after we reached the Matutan Range and some of them made the trip into Davao with us; when we made the ascent of Mount Apo we spent several nights in their villages and used the people for guides and carriers. The large man in the center of the group, shown by Plate I, is Tongkaling, the chief of all these people, surrounded by some of his dependents. Tongkaling is a headman and wears the badge given him by the authorities of the Moro Province. Plate II is a view of the chief's house. Although the Bagobos wage petty wars among themselves, they have caused little trouble for Americans. Indeed, many of those nearer the coast work on the American plantations and do fairly well.

The men of this tribe present a better appearance than do the women, and in physique and features they surpass most of the other natives in the Archipelago whom I have seen, and I have seen many of the tribes. It is said that, like the ancient Spartans, they strangle at birth all deformed children. Their hempen garments are highly decorated with shell ornaments and with Italian beads which they procure from the Chinese. They mark with some sort of design nearly every article they use, as can be seen by examining the old chief's shield and spear. The men are greatly addicted to the practice of tattooing; the women are not tattooed to any extent, but wear brass rings on their fingers, ears, necks, toes and ankles.[3]

The *agong,* shown in the upper left-hand corner of Plate I, is known and used all over the Malay region. I have seen one man play on as many as six of these at a time. It is the chief musical instrument in these districts, is made of brass and is imported from Singapore. *Agongs* cost from 20 to 50 pesos Philippine currency each and are the measure of a man's wealth. Tongkaling had forty of these hanging about in his house at the time I visited him. In addition to the *agong,* the Bagobos have a rude drum, not essentially different from any other drum, a bamboo fiddle and a reed flute. The music is exceedingly simple and monotonous.

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[1] Sawyer, F. H.: Inhabitants of the Philippines, Charles Scribner's Sons, New York (1900), 353.

[2] *Globus* (1882), 42, 219–222; *Globus* (1897), 71, 19–20.

[3] Anyone traveling in the Bagobo country will do well to lay in a stock of beads, brass wire and cheap jewelry.

The entire system of living among the Bagobos is feudal, and slavery is practiced among them. The man shown in the extreme left in Plate I is a Bilan, and judging from the treatment received by him at the hands of the Bagobos, it is not hard to believe that he is a slave. These people do most of their traveling on horseback, riding very sturdy little ponies, usually adorned with bells which they buy from the Chinese and which they also use to decorate their clothing and pouches. The Bagobos have been aptly termed "horse Indians."

It is not my intention to present here a complete account of this interesting people, as I have had neither the time to study them nor the necessary training as an ethnologist to enable me to do so. However, I wish to give some interesting information which I obtained from Governor Allen Walker, of the district of Davao, relating to a most interesting tribal religious custom. The special event which I am about to relate took place the week before we arrived in the town of Digos, but before presenting this account it may be well to give a few extracts from the Jesuit letters bearing on this religious custom.

Mr. Christie, of the division of ethnology of this Bureau, in searching through the letters written by the Jesuit missionaries in Mindanao, found references to human sacrifices. These references are in letters dated in the years 1885 and 1886. They have not been copied *verbatim,* but synopses are given. The first letter, that of Father Gisbert to the Father Superior, dated Davao, April 2, 1885, says, in substance:

> The Bagobos have been making more human sacrifices, notwithstanding their promises to the contrary and the vigilance of the writer. A slave girl from Cauit mission, named Padal, was sold and sacrificed; also a pagan named Maguana. "Captain Atas" also made a sacrifice a short time ago.

The second letter from the same father to the fathers and brothers at Veruela, dated Davao, January 4, 1886, contains the following interesting information:

> The Bagobos have two feasts a year, one before planting and the other after harvesting. The latter is innocent enough, and is known as the "women's feast." All gather in the house of the headman late in the afternoon, where they eat the best to be had and drink a beverage of fermented sugar cane juice. They also have instrumental music, singing and dancing, and the party usually breaks up about morning
>
> The other feast is quite different, and though comic in some of its details, is in its principal part, tragic, criminal and disgusting. The tragic part comes

first; the people gather in some dense forest, taking all necessary precautions that the authorities and missionaries learn nothing of their doings or whereabouts. They take their victim, usually a slave, and tie him securely. Then, knives in hand they dance around him hacking him until he is dead. During this operation they shriek like maniacs, provided they are not too close to a Christian settlement, or otherwise likely to be discovered. If they think they are in danger of discovery they gag their victim, refraining from all noise. Then they retire to the headman's house, carrying branches in their hands which they later place in a big joint of bamboo. This is the altar and is the only thing approaching an ornament about the place. Here they eat, drink, dance and play innocently enough. At this point an old man, usually the headman, assumes the principal part. He sits by the altar, takes a glass of their wine in his hand, and, in company with his companions, addresses the "great devil," whose feast they are all celebrating, as follows:

"Darago, we celebrate this feast in your honor both willingly and joyfully, and we offer you the blood of the victim, together with this wine which we drink, so that you may be our friend and accompany us and assist us in our wars."

This being said, they recite a form of litany in which all the most noted *Daragos* known to them are mentioned, the whole assembly reciting these names in unison.

The Bagobos believe in a future state, and hold that each person has two souls. God, or *Fiquiama*, is very good, they say, and he made all things, although it is true that he was assisted by some minor gods who are subject to his order. These minor gods are *Mamale*, who made the earth; *Macacoret*, who made the air; *Damacolon*, who made the mountain; and *Macaponguis*, who made the waters. One of the two of each individual's souls goes to hell and the other to heaven; for they believe that the devil has to do with them in the next world as well as in this, and they give him about equal rights with God. They hold that the devil is very bad, likes blood, and is the cause of all disorder. Thus, they forget good and in all things serve and adore the devil. When a couple of rank marry, there is a human sacrifice to keep away sickness, etc., all of which calamities are attributed to the devil. When a contagious disease makes its appearance, or when there is fear of approaching death, a great gathering is held for the purpose of arranging a human sacrifice and praying to the devil to let them live in consideration of this generous offering.

According to Bagobo customs, the proper time for a sacrifice is when a member of a family dies, and before the termination of the "Lalaoan" or mourning. At such a time a sacrifice is announced much in the same way as Christians would proclaim a feast day or a pilgrimage. At the appointed time all assemble in a place agreed upon, or at least one person from each family in mourning. Their numbers frequently reach fifty or more persons. There is then an assessment to cover the purchase price of a slave and he who pays the largest part is allowed to strike the first blow. Usually the victim cries out while he can and begs for mercy, but his voice is lost in the shrieking of his assassins who make one of the most horrible uproars imaginable. As has been said, when a sacrifice is made near a Christian community there is no shouting and the victim is gagged.

The third letter from Father Gisbert to the fathers and brothers at Veruela, dated Davao, February 8, 1886, continues an account of Bagobo customs:

How did the writer of the foregoing letter acquire so exact a knowledge of Bagobo custom? True, he did not witness a human sacrifice; but the account

given by him in the preceding letter was furnished by baptized Bagobos and also by intended victims that missionaries have rescued.

The Bagobos are very superstitious, and their customs are frequently very ridiculous. When one of them becomes possessed of an evil impulse (and the appearance of a snake in the house, the breaking of a pot on the fire, etc., is sufficient for this) he calls on his *Matanon* to liberate him from evil through his great knowledge. *Matanon*, the protector of the religion and customs of his forefathers, makes with his knife a doll in the form of a man; and then addressing God, says: "Oh God, creator of men, trees and all things, do not deprive us of life, but receive in place thereof this piece of wood which has our form." This ceremonial over, they throw a sack into the water which contains a little rice or "*morisqueta*"[4] (sometimes it contains the wooden doll also), and this is even accompanied occasionally by a cock. In this way the trouble is relieved. When they are sick they make offerings to the "*Diuata*" on their "*tambora*," which consists of a plate placed on top of a piece of bamboo set upright in the ground. On this plate are placed "*buyo*"[5] and tobacco, and then they address God, saying: "We offer you this, give us health." When they visit the sick they bind wires around their wrists and ankles to keep the "*limocod*" or soul from escaping. And when one dies he must have his ration of rice to eat on the way. Upon gathering the harvest of rice or corn, the very first grains obtained are offered to the "*Diuata*" and they would not think of selling or otherwise using any of the crop for themselves until their field implements have been fed, for these have cleaned the field.

The song, or cry, of the *limacon*[6] is for them the voice of God, and presages good or ill according to circumstances. Thus when the *limacon* cries out, all who hear it pause and look around. If, for example, they see a fallen tree, the *limacon* tells them that they should not continue their journey for they will meet the same fate as the trees; whereupon they turn back. Should they not behold anything that especially augurs ill, then the cry of the *limacon* has but assured them of the successful outcome of their journey, and they continue on their way. A sneeze is a bad augury, and when anyone sneezes at the beginning of a journey, the journey is postponed until the next day.

Few thefts are committed among Bagobos, for they believe that a thief can easily be discovered through their wonderful "*bongat*." This consists of two small joints of bamboo, containing mysterious powders. He from whom something has been stolen and who wishes to find the thief, takes a hen's egg, makes a hole in the shell and into this injects some of the mysterious powders already referred to and then places the egg in the fire. Should he desire the death of the thief, he has only to break the egg. But, as frequently happens, the thief may be a relative or a person very dear to the operator; and so oftentimes the egg is not broken in order that a more happy solution may be had; for in any case when all methods save breaking the egg have been resorted to, and the latter is done, no matter where the thief may be, he will at once betray himself by shouting "I am the thief, I am the thief!" And this is due to the sharp pains he is said to feel throughout his body. Once discovered, he can be cured by placing some of the powder from the other joint in water and bathing his body with it. This practice is very common among the pagans and Moros here. A converted Bagobo, named Anas, gave the writer a "*bongat*," the possession of which caused the former to be greatly feared while he was a pagan.

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[4] Cooked rice.

[5] Buyo is composed of the fruit of the betel-nut palm, locally known as *bonga* (*Areca catechu* Linn.), the fresh leaves of *Piper betle* Linn., and lime, to which tobacco is sometimes added. It is extensively chewed by the natives of India and Malaya.

[6] A small, brown pigeon, of the genus *Phapitroron*.

In a fourth letter, dated Davao, July 26, 1886, the following information is given:

The writer cites the case of one Maglandao (not a slave), who obtained a pair of earrings for which he could not pay; whereupon he agreed with the owner to work out the price, which was about 10 pesos. Some days later the owner of the earrings grew angry with him over some trivial matter and shot him, wounding him mortally. The offender was not a Bagobo, but hearing that the Bagobos were about to make a sacrifice, he sold them the dying man for fourteen cavans of rice. The purchasers were well pleased with the bargain, since they secured the victim cheap, as was also the other party to the transaction, for he had obtained sufficient rice to maintain himself for a year. The writer learned of this from a Bagobo who assisted at the sacrifice, and whom the writer baptized later. Both pagans and Moros make a business of selling victims to Bagobos. When a certain governor of the district of Davao expressed his disgust at this practice, a Bagobo replied: "Is it not lawful to spend your money as you wish? Our slaves are the same as money to us, and we dispose of them agreeably to our pleasure and customs." The writer holds them to be more barbarous than the Ammonites who sacrificed to Saturn; for these made sacrifices only at a certain period of the year, while the Bagobos make them continuously.[7] Every rancheria has its feasts in honor of the devil every year. He is known as *Busao, Mandaragan, Darago,* and by many other names. When a feast is to be held in his honor, there is a gathering in the house of the headman where all eat, drink, sing and dance very gaily; and the only objectionable feature of the occasion that one can see is the drunkenness commonly attendant on such occasions. They pass around their liquor, inviting one another to drink, and finally calling upon the master of the feast for a speech, they drink to the great *Darago,* promising to follow and honor him always, and like their forefathers, give him plenty of human blood to drink to secure his friendship and assistance in their wars. The inexperienced observer, who does not understand their language, sees nothing surprising in this; while he who knows something of the Bagobos will at once recognize the proof of the previous day's sacrifice namely the branches placed in the joint of bamboo before which the master of ceremonies invokes the *Darago,* for these tell the story.

When a contagious disease makes its appearance, or when a relative dies, they interpret this to mean that the *Darago* wants more victims, and immediately take steps to appease him and thereby save themselves from death. At the moment of sacrificing they say, "Aoaton mo ian dipanoc ini Manobo, timbac dipanoc co, so canac man sapi," which means "Receive thou the blood of this slave as if it were my blood, for I have bought it to offer it to thee." These words they pronounce while slashing the victim with their knives. As the great devil feeds continuously on human victims, these sacrifices must be numerous.

The following is taken from the *Historia de Mindanao y Jolo,* by P. Francisco Combes, S. J., pages 63 and 64:

The Bagobos, of a pure Indonesian race, are firmly planted on the smaller ridges of the southeast of Apo and have, therefore, as neighbors the Guiangas, the

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[7] This is contradicted in Governor Walker's report. See p. 195.

> Atas and the Calaganes. Moreover, they practice the barbarous customs of human sacrifices, are bold, warlike and given to drunkenness; almost all of them are of fine presence, for they immediately strangle deformed ones at birth. There are more than 12,000 of them, of whom in 1887 some 800 had been baptized:

Montano and Schadenberg, and the Jesuit Fathers Gisbert and Doyle, have made especial studies of the Bagobos. Since the year 1886 only one report of a sacrifice has been recorded. It is referred to, but with no details, by Sawyer. Every detail of the following story was thoroughly investigated and is vouched for by Governor Walker and Captain Plattka, senior Constabulary inspector of the district, and I have been furnished signed copies of their reports by General Bliss, governor of the Moro Province, with his permission to publish the facts. The event was the offering of a human sacrifice to the god of evil. The place was Talon and the date December 9, 1907. I give Governor Walker's report almost in its entirety, omitting only the names of the participants:

> In addition to a pencil report made under date of December 20, 1907, regarding a human sacrifice made by the Bagobos at Talon near Digos on December 9, 1907, I have the honor to submit herewith a full report of an investigation held by myself and the senior inspector of Constabulary at Davao.
>
> We left Davao on the morning of the 27th of December and arrived at Digos in the afternoon of the same day. An order was immediately sent to the Bagobos of Talon to come down to Digos to meet us.
>
> On the morning of the 30th the entire population of Talon, men, women and children to the number of almost one hundred and fifty, arrived at Digos. They were informed that it was reported that a human sacrifice had been made at their town and that the authorities desired to know if it was so.
>
> Datu ——— replied that it was true that a sacrifice had been held as stated and that both he and his people were ready to tell all about it, as to the best of their belief they had committed no crime but had only followed a religious custom practiced by themselves and their ancestors from time immemorial.
>
> From the statement made by Datu ——— and his followers, it appears as follows:
>
> That the Bagobos have several gods,[8] "*Baculad*," god of the spirits; "*Aganmole Manobo*," god of good, and his wife, the goddess "*Diuata*," "*Mandarangan*,"[9] the god of evil (corresponding perhaps to our devil), and to whom sacrifice is made in order to appease his wrath, which is shown by misfortune, years of drought or evil befalling the tribe or its members; it is at times necessary to offer him human sacrifice so that he will allow the spirits of the deceased to rest. They say that in case a Bagobo of rank or influence dies and his widow is unable to secure another husband it is necessary for her to offer sacrifice to appease the spirit of her departed husband in order that she may secure another. In order that these sacrifices be not made too frequently it is customary for the old men of the town to gather once each year during the time when a certain constellation of seven stars, three at a right angle to the other four, are seen in the heavens to the east at 7 o'clock in the evening; this is said to occur once a year during

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[8] The fact that the names of the Bagobo gods as here given differ from those in quotations given above may be due to a misunderstanding of the interpreter or it may be that Bagobos in different localities have different names for their gods.

[9] *Mandarangan* is believed by the Tagakaolos to live in the crater of Apo.

the first part of the month of December. This constellation of stars is called by the Bagobos "Balatic" and is the sign of the sacrifice; that is, if a sacrifice is to occur, it must take place during the period when the stars are in this position. The old men meet and decide if enough misfortune has overtaken the tribe or village during the period since the last sacrifice to render necessary another tribute to the god of evil. It is not necessary to offer a sacrifice for each evil, but when the misfortunes are considerable, a sacrifice is held to cover all.

In this case it appears that two widows went to the datu and requested that he arrange a sacrifice to appease the spirits of their departed husbands who were bothering them. The datu called a meeting of the old men; there were present, besides himself, three other Bagobos, and these four decided that as there had not been a sacrifice since the great drought (about three years before), and that since that time many evils had befallen them, it would be well to offer a sacrifice. These four men were sent out to find a slave for the sacrifice, the finder becoming the chief of ceremonies. A henchman of the datu purchased from a Bagobo a Bilan slave boy named Sacum, about 8 years old, who was deaf and cross-eyed, and who had other defects of vision making him of little or no value as a laborer. This boy was originally received as a slave from a Bilan as a wedding present, when the Bagobo married the Bilan's daughter about a year before.

The henchman of the datu agreed to pay five *agongs* for the boy and took him to the house of a friend where arrangements were made for the sacrifice by calling on all who, for any reason had need to appease the evil spirits, to come and take part. Three days after the slave was brought to this house, the people met at Talon near the Inolia River a short distance from the house, this being the regular place of sacrifice. Among those present were sixty prominent men and twenty-two women of the tribe. (The datu whose picture is shown on Pl. I was there.)

Being taken from the house, the boy Sacum was seated on the ground near the place of sacrifice. He was naked but no other preparation was made with regard to his person. Upon a platform or bench of bamboo about 2 feet high and a foot or two square was placed a small basket or receptacle made of the bark of the *bunga* tree, in which each person present and taking part in the sacrifice placed a piece of betel nut; over this the men placed their head handkerchiefs and over the handkerchiefs the women laid strips of the bark of the *palma* tree. Upon this the men laid their bolos, and spears were then stuck in the ground in a circle around the platform. Next, the datu, as chief of the sacrifice, made an oration which was about as follows:

"O Mandarangan, chief of evil spirits and all the other spirits, come to our feast and accept our sacrifice. Let this sacrifice appease your wrath and take from us our misfortunes, granting us better times."

After this the boy Sacum was brought forward, and placed against a small tree about 6 feet high; his hands were tied above his head and his body was tied to the tree with rattan strips at the waist and knees. A spear was then placed at his right side at a point below the right arm and above the margin of the rib. This lance was grasped by the two widows who, at a signal from the leader of the sacrifice, forced it through the child's body, so that it came out on the other side. The spear was then immediately withdrawn and the body cut in two at the waist by bolos in the hands of two Bagobo men, after which the body was cut down and chopped into bits by the people present, each of whom was allowed to take a small portion as a memento of the occasion, the remainder of the body being buried in a hole prepared for it.

It is said that the child was deaf and almost blind and that he did not realize

> what was to happen to him until the moment he was tied, when he began to cry; and furthermore, that death was almost instantaneous, the only cry being one uttered when the spear first entered his side.
>
> Datu ———, a man about 60 years of age, says that in his life he has attended or officiated at fifty human sacrifices, more or less, both among the Bagobos and Bilans, and that human sacrifice is also a practice among the Tagakaolos, although he has never been present at one held by that tribe. The Bagobos do not sacrifice any but old and decrepit or useless slaves captured from other tribes, but the Bilans sacrifice even their own people. Being asked if it was customary to eat any portion of the body sacrificed, my informant replied that it was not customary nor did he know of any case where such a thing had occurred.
>
> The last sacrifice previous to this was held at Talon during the year of the drought (about 1905) when a Bilan slave, an old man who was paralyzed in one arm, was sacrificed by Datu ———, his master. When asked if the sacrifice of an animal would not do as well as that of a human being, they said no, better to have no sacrifice at all. They appeared utterly unconscious of having committed any crime, told their story with frankness, said it was a matter not talked about among their own people, but that if we wanted to know the facts they would give them to the authorities. They maintained that the offering of human sacrifices by their tribe was an old custom and as far as they knew was the only way to appease the wrath of the evil spirits, but they said if they were ordered to give the custom up they would do so even if the devil got them all.
>
> In view of the facts in this case as brought out in the investigation, it is not thought that it is a case for prosecution before the courts, but rather one for religious instruction in so far as it is possible to give it. When it is considered that only a year and a half ago these people could not be approached by a white man without taking to the brush, and that now they will come down out of the mountains to meet the officials to discuss a question of this kind, it is evident that they have great confidence in our Government.
>
> I explained to them that human sacrifices were wrong and would not be allowed by our Government, and furthermore that I could not let them off, but would write and explain everything to the provincial governor, who would decide what was to be done in the premises. These people have promised me that if I would assist them to secure a good location near the coast, they would move down from the mountains. I have promised them my assistance in the matter and I intend to try and get them down to a point near Digos in the near future.

These accounts differ in minor points, but the essential details agree very well. I know of no white man who has witnessed this event. The fact that none of our party learned about the sacrifice until we had passed through the place where it took place shows how secret the whole affair was kept. The native foreman on a near-by American plantation, where we stopped for a day or two, was the principal actor in the scene.

The Bagobos are, on the whole, very tractable and well disposed toward Americans, in spite of this primitive and bloody custom. I lived among them for several days and felt not the least anxiety. Good judgment and tact in dealing with them will doubtless enable the provincial officials to induce them to give up this practice even though they have made human sacrifices for many years.

WARREN D. SMITH.

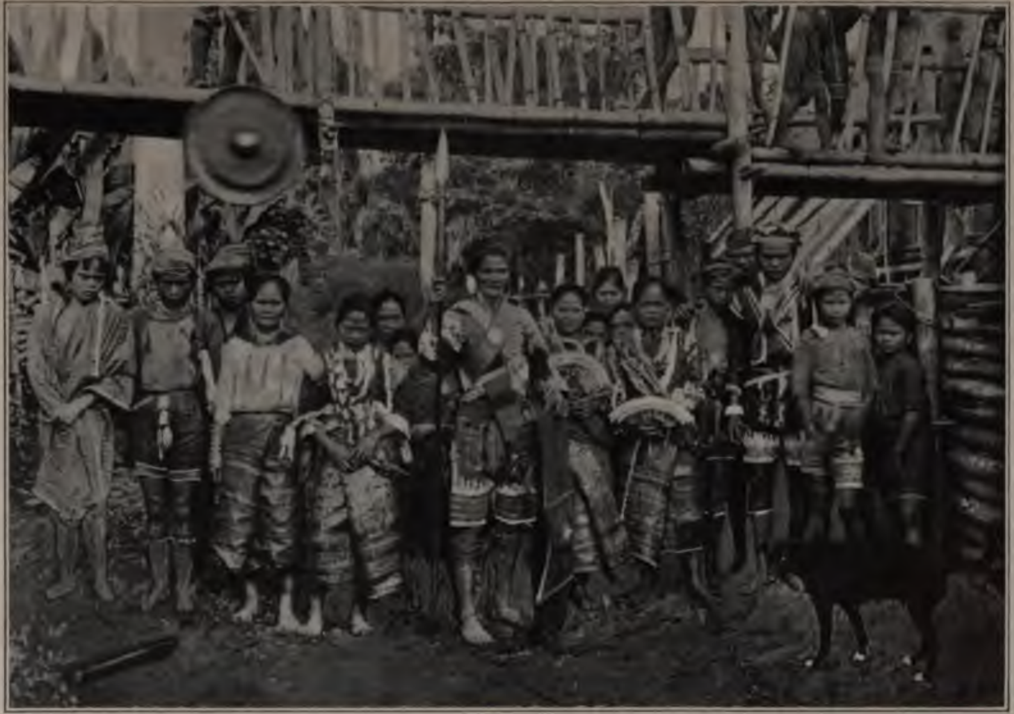

PLATE I. TONGKALIN AND HIS HOUSEHOLD.

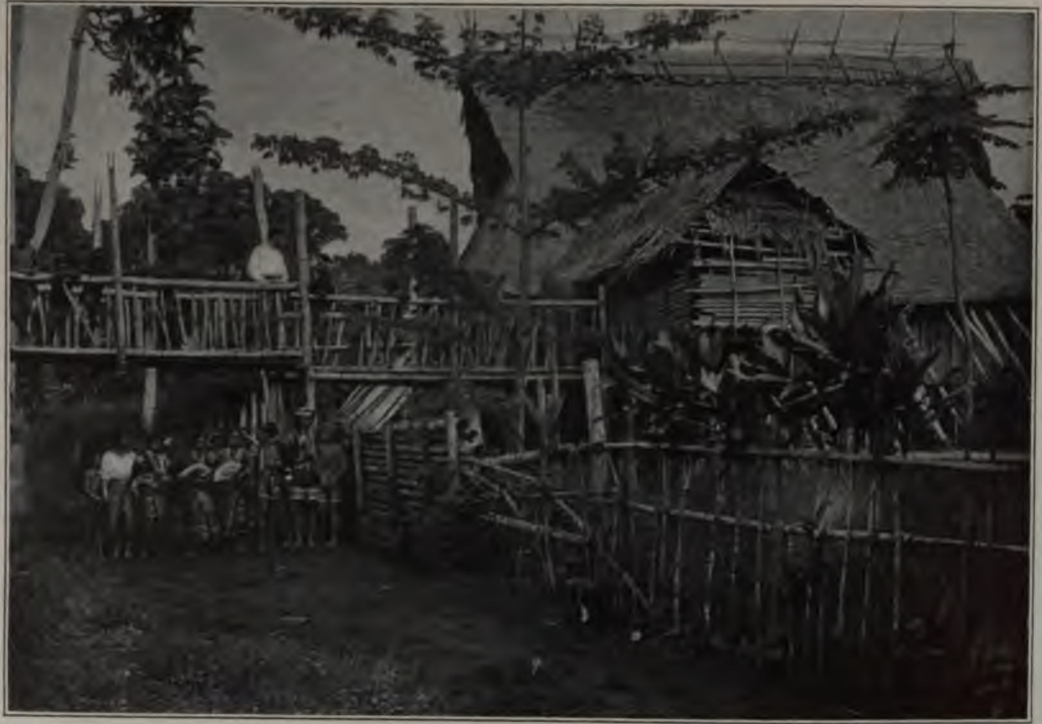

PLATE II. TONGKALING'S HOUSE ON THE EASTERN SLOPE OF MOUNT APO.

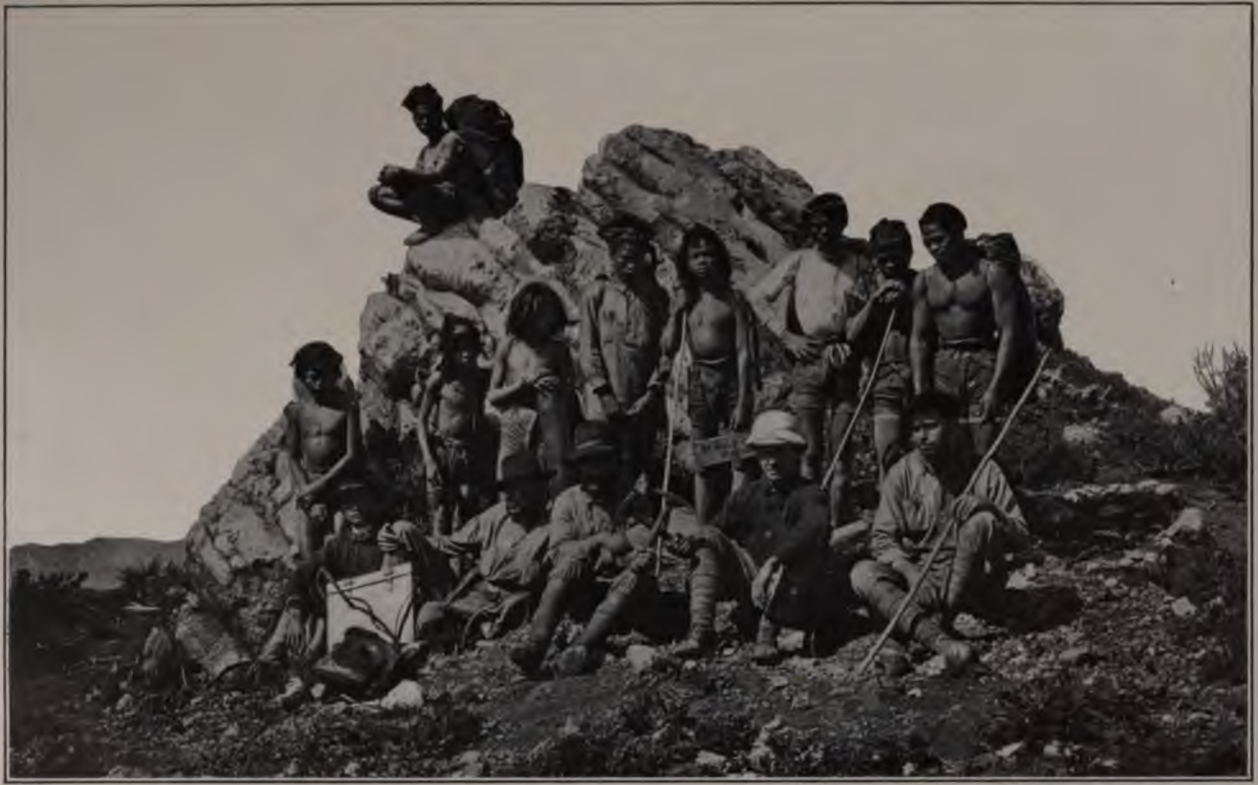

PLATE III. OUR PARTY ON THE SUMMIT OF MOUNT APO (THE PORTERS ARE BAGOBOS).

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THE TINGGIAN.[1]

By FAY COOPER COLE.

(From the Field Museum, Chicago, and the Bureau of Science, Manila, P. I.)

INTRODUCTION.

For several years the Field Museum of Natural History has been desirous of making a thorough investigation of the various Philippine peoples; but it was not until 1906 that money was available for this purpose. Through the generosity of Mr. Robert F. Cummings, of Chicago, ample funds were provided for a series of investigations to extend through four or six years. The first party to begin work under this appropriation reached the Islands in June, 1906, and was followed by a second in January, 1907.

Influenced by the evidences of a highly developed ceremonial life found by Mr. Dean C. Worcester, during his visits to Abra, and by the suggestions of Dr. Paul C. Freer and Dr. Merton L. Miller, the writer decided to make the Tinggian the initial field for work. The studies carried on have been along the lines of general ethnology (with special emphasis placed on the material culture, social organization, customs, religion, mythology, and decorative art), language, and physical anthropology.

The following article lays no claim to completeness, as the investigations are still in progress; yet it seems advisable, from time to time, to publish such material as may be of interest to workers in other fields.

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[1] The name Tinggian is spelled throughout this paper in accordance with the form adopted by the division of ethnology of the Bureau of Science. In all native Philippine words in which the hard sound formerly represented by "c" occurs this sound is represented by "k," as in "Ilokos."

GEOGRAPHICAL DISTRIBUTION AND MIGRATIONS.

The Tinggian culture group has its stronghold in the subprovince of Abra. To the north and west, it extends into Ilokos Sur and Norte as far as Kabittaoran (near Dingras). Manabo, to the south, on the Abra River, is the last pure Tinggian municipality; but Barit, Amtuagan, Gayaman, and Luluno are Tinggian mixed with Igorot from Agawa and Sagada. Villaviciosa is an Igorot settlement from Sagada and its vicinity; but Bulilising (near Villavieja) is strongly Tinggian. I am told that Sigay in Amburayan is largely made up of Tinggian emigrants from Abra, and that a few rancherias in Lepanto are also much influenced. In Ilokos Sur, south of Vigan, the whole non-Christian population is commonly called Tinggian, and the people readily apply the name "Itneg" (the name by which the Tinggians distinguish their own people) to themselves. A careful survey, however, shows that very few true Tinggian towns exist in that section. A small number are of mixed Tinggian and Igorot population, while the balance are Igorot, somewhat influenced. I failed to find any Tinggian towns south of Santa Lucia. North of this point are Ballasio, Nagbuquel, Vandrell, Rizal, Mision, Mambog, and Masinget. Towns of mixed population are Kadangla-an, Pila, Kolongbuyan (Sapang), and Montero. The other villages are Igorot colonies from Titipan, Sagada, and Fidilisan.

Along the headwaters of the Saltan River in Balbalasang, Talalan, Sesekan, Patikian, and Salegseg, we find a people who in dress and looks are much like the Tinggians, and they are generally so classed. These people claim a common ancestry with those of Linas, Gakab, Malibkum, and the Gobang group who originally came from Bolalay-yo (near Patikian). There has been considerable intermarriage with the Igorots, and extensive migration into the Tinggian belt, but very little movement from Abra to this section. The Gobang group (including the villages of Bo-ok, Kapnay, Dewangen, and Kayabong), which is the least influenced of any of this region, must, I believe, be classed with the Kalinga. It seems, then, that here we are dealing with a population made up of Tinggians, Igorots, and Kalingas, but that, with the exception of dress, the Tinggian influence is insignificant.

In the extreme northern end of the island, in the vicinity of Bangui and Claveria, and again along the Apayao River is a people who call themselves "Ishneg," and who closely resemble in size, features, and color the people of Abra. Commissioner Worcester first indicated his belief that these people were wild Tinggians. With a view of gathering more data on this point, the writer visited these regions in the early months of this year. The material from this section has not been carefully worked over; but there is much to indicate that these people are of common stock with the people of Abra. However, the separation must have taken place at a remote period, before the Tinggian received the highly developed ceremonial life which distinguishes him from his neighbors. Because of the many differences in customs, and the space allowed this article, no attempt will be made to deal with the Apayao branch at this time.

It is difficult to secure reliable information concerning the Tinggians in early and pre-Spanish times; but all the tales of migrations tell of movements from the coast country far back into the mountains, as the pressure of the "Christians" was felt. In many cases there was a return to the lower valleys from which these people are again being slowly driven by their Ilokano neighbors. They have no tales of an earlier home than Luzon; but the Apayaos have well-defined stories of having come from the Babuyanes (to the north of Luzon) settling near Pamplona, Abulug, Nagilyan, and Aparri, and to have reached their present home since the advent of the Spaniards.

The migration into Abra from the vicinity of Sagada has already been noted. A second, considerable movement took place from Balatok to the Ikmin River Valley, where the emigrants founded the towns of Danok, Amti, and Doa-angan. Tue is a settlement direct from Balbalasang; and the towns lower on the Buklok River have received many additions from there, also from Gina-an and Lubuagan. All of the villages on the headwaters of the Binongan have received emigrants from the Kagayan side; while Agsimao and other towns of the Tineg group are largely made up of Kalingas and Apayaos. There is an approximate population of twenty thousand in the towns properly classed as Tinggian (Apayao excepted).

PHYSIQUE, DRESS AND CUSTOMS.

The center of the Tinggian belt is reached from Vigan, in Ilokos Sur, by a trip on a raft which takes a day, or on horseback along the Abra River. From Bangued as a center, the settlements radiate in all directions. To the north and east, they extend two and three days' trips into the mountains. A few of the larger municipalities are in the broad valley of the Abra or its main tributaries, where with extensive fields and domesticated animals the Tinggian has not only successfully competed with his Ilokano neighbors, but has often surpassed them. In the mountains, his efforts have been more restricted; but with his terraced fields he has managed to bring much of the rugged country under cultivation. Even the steep mountain sides, where irrigation is impossible, are cleared, burned and planted to corn and mountain rice.

The rivers contain quantities of small fish, eels, and shrimp, and many are the devices employed for their capture. By nature the man is a hunter; and he is poor, indeed, who does not own one or more dogs for use in the chase. In the leisure season, following the rice harvest, it is a common sight to see ten or a dozen men with their spears, nets and found in each town. The largest of these, which is nearly of the size of a dwelling, but which has no sides, is known as *balao-a*; another closely resembling it, but much smaller, is *kalangan*; while a third, comparable in size but without a pointed roof, is *tangpap*. A miniature house built near a rice granary, some banana trees, or in a distant field, is *bawi*. Four poles (three usually of bamboo, and one of a resinous tree) support a small platform several feet above the ground, and this is known as *pala-an*. A bamboo pole about 10 feet long has one end split into several slits; these are forced apart and tied with twisted bamboo, and into the basket thus formed a jar or coconut shell is placed, while decorations of leaves and rice stalks are added. These poles, known as *saloko,* are commonly found planted at the entrance of the town. Miniature baskets of this nature hold an egg, and are fastened to the roof of a house. Coconut husks decorated with feathers and containing the legs and head of a chicken, are suspended from a pole; they are known as *baneet* (fishhook). In addition to these permanent spirit structures, a number of small buildings are made for special ceremonies and are destroyed after they have served their purpose. The *balao-a* and *kalangan* are used as general meeting places for the women when they spin or weave, cotton is beaten there and tobacco is hung in them to dry.

Aside from these buildings and the houses, a Tinggian village will contain a number of corrals for carabaos and cows and a few gardens and seed beds. Surrounding the settlements are the rice bins.

It has already been noted that the Tinggian has extensive rice fields. To these he devotes the greater part of his time. When the rains begin, the seed beds are planted, fences are repaired; and when the soil has become moist, it is plowed and harrowed. Both men and women work at transplanting the rice; but the men watch and care for the fields during the season of growth. When the grain has ripened, the whole population goes to the fields to cut and bind the rice and to carry it to the inclosures for drying. From June to November much of the day is spent in the paddies, but it is the happy time for the people. Approaching a group of workers, you can hear one or more singing the *daleng,* in which they tell of current events or topics of general interest, or perhaps some youth is singing a love song to the girls.

Aside from rice, the Tinggian raises maize, tobacco, beans, sugar-cane for *basi* (the native fermented drink), *camotes* (sweet potatoes) and *aba* (*gabi*) in considerable quantities. Many other vegetables and roots as well as fruits are used for food to a considerable extent.

Many excellent baskets are made; these are chiefly the work of the man. The woman is the potter and the weaver of nearly all the clothes and blankets used by the family, and she also plaits the mats. All household duties are left to her; but when at home the man will assist in the care of the children, especially the babies. Hunting and fishing employ the man's extra time.

During the dry season bonfires are built at night in various parts of the village; about these the women will gather to spin and the men to make nets, while some good singer or story teller will entertain with tales of the adventures of some mythical hero, of contests with strange huge animals, or of beings with supernatural power.

GOVERNMENT.

The old men of a village constitute its ruling class. Of this number, there is usually one who by reason of his wealth, integrity, or superior knowledge of the customs, is called *Lakay,* and to him, all matters of dispute are brought for adjustment. If the case is of importance, or difficult to settle, he will summon the other old men who will deliberate on and decide the questions at issue. They have no means of enforcing their decisions on the people other than that it is custom to obey, and the offender is ostracized until he has met the conditions imposed. A pig and a jar of *basi* are furnished for such a gathering and the person judged to be in error must stand the cost of the meeting. A young man has little or no voice in the conduct of affairs; even his own life and actions are largely regulated by his older relatives. The woman seldom participates in the general councils, but in daily life she is quite as independent as her husband and with him has equal rights to bring her grievances to the attention of the *Lakay.*[2] The wealth and the standing of a man's ancestors in a community have much to do with his position and power, but age outweighs all other considerations. Since the American occupation local self-government has been established in many of the towns. The contest for office and government recognition of the officials is tending to break down the old system and to concentrate the power in the *presidente.*

In daily life there is no strong class distinction (with the exception of the *pota*), but during ceremonies and functions, one class is sharply marked. The members of this are known individually and collectively as *alopogan;* for lack of a better name, I shall call them mediums. There is no organization to this class: men or women who are named by the spirits to become *alopogan,* either through other mediums, in dreams, or by trembling fits when they are not cold, go to one already accepted by the *anitos* [3] and from her learn the duties which they are to perform. First there are long *deams,* or set prayers, which the spirits taught the first Tinggians. These must be memorized word for word. Then the objects desired by each spirit must be learned, so that no visiting *anito* may be offended by failure to receive his regular gift. The greatest task is to learn the details of the various ceremonies of which there are more than twenty, varying from a half day to seventeen days in duration. Many months or even years may be required to learn all the things which must be done. When all is mastered, the candidate must secure her *peling.* These are a certain variety of sea shells which are put in a small basket with a hundred fathoms of thread. If it is possible she will use the *peling* of some dead medium but failing to secure them new shells will be obtained. A small pig is killed; and its blood, mixed with rice, is offered to the spirits. The liver of the animal is eagerly studied, for it will give the sign whether or not the *anitos* are satisfied with the new medium. Should the liver be spotted, further preparation or offerings are desired and until a favorable sign is received, no attempt is made to summon the spirits. Certain candidates are never accepted by the *anitos*; but they are not barred from making the *deams* and aiding in the direction of ceremonies.

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[2] An exception to this is the *pota,* a class made up of those women who live with men not their husbands. Such a woman is held somewhat in contempt by the other women; and she is seldom seen at the camp fire gatherings or in other houses. Her children belong to the father; and she has no right of appeal to the old men, except in cases of cruelty. Men with concubines do not suffer in the estimation of their fellow-men, but are considered clever to be able to have two or three women in addition to their wives. The *pota* is usually faithful to one man, and prostitution, as such, is almost unknown.

If the signs are favorable, the medium may now conduct ceremonies alone and summon the spirits. She places the offerings before her on a mat and after striking a dish repeatedly with her *peling* (to call the attention of the spirits) she covers her face with her hands and trembling violently, begins to sing, calling on the *anitos* to enter her body. Suddenly she becomes possessed of a spirit and is no longer herself: all her actions are those of a higher being, and as such she talks with the people, asking and answering questions, or directing what shall be done to drive away the sickness for which the ceremony has been made. At one time only can she summon the spirit of the dead; just as the body is to be lowered into the grave, the spirit may possess her and through her, talk to his relatives.

The pay of the medium is small—usually a portion of some animal slaughtered for the ceremony, a few bundles of rice and some beads; but the taboos are severe. At no time may a medium eat of carabao, wild pig, wild chicken, or shrimps, nor may she touch peppers.

RELIGION.

To understand the Tinggian at work or at play, it is necessary to understand his religion, for to him it is very real, influencing every act of his daily life. A great and powerful spirit known as *Kadaklan* lives in the sky, and to him all other spirits are subservient "like soldiers."

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[3] Spirits *sui generis.*

His wife, *Agemem,* who lives in the earth is also powerful. Two sons have resulted from this union, and they are quick to punish any disobedience of their father's commands. *Kaboneyan* is the friend and helper of the people. It was he who taught the Tinggians how to plant and to harvest, how to overcome evil signs and to foil the designs of ill-disposed spirits. His cave in the mountains contained the wonderful tree on which grew the agate beads so prized by the women; in it lived the jars which could talk and move; while from the same cave came all the valuable *gansas*[4] which the people use. Nearly all the details of ceremonies and celebrations were taught by this friendly spirit. Further to bind himself to the people, he married "in the first times" a woman from Manabo. More than a hundred and fifty other spirits, some good, some evil, are known by name and at some time or other they visit the people through the mediums.

In his waking hours the Tinggian does not fear many of the spirits. He converses freely with them when they come to the ceremonies; to the friendly ones he shows the utmost respect; to the ill-disposed, he is insolent, makes fun of them, or lies to and cheats them. At night his attitude is changed. In the darkness he is no match for the unseen beings and every door and window is tightly closed to keep them out. If by chance he is compelled to sleep on the mountain or in the open he takes every precaution to ward off their evil machinations. *Sobosob*[5] leaves should be his bed, for this plant is distasteful to the spirits; branches put at his head will avert an early death by preventing one of them from expectorating on him as he sleeps. No work nor trip of importance is planned without first observing the signs and even when the undertaking has been begun an evil omen will cause a change or a postponement. Offerings of food and drink are made at the beginning and the completion of an important work, whether it be the planting and harvesting of the rice, or the completion of a house or field. When illness visits a member of the family, it is the work of an *anito* and the medium is called. She prepares for the ceremony which she thinks is needed and the spirits are summoned. Should she have erred in the selection of the ceremony the proper one will be substituted. The many spirit houses mentioned earlier in this article demand ceremonies of varying lengths, and are visited by many spirits. *Balao-a, kalangan, tangpap,* and often *pala-an* demand several days for their completion and are visited by nearly all the spirits, including the most powerful.

The spirit of a dead man is called *Kalading.* It may go at once to its home *Maglawa*—somewhere in the sky—or it may remain nearby until the body is buried. Often it stays close to the house to punish any member of the family who leaves the town before the ten days taboo is passed. It returns for the *layog*, a ceremony made about six months or a year after the death, and sometimes on other occasions. The *kalading* resembles a person, but can not be seen and in *Maglawa*, he lives much as he did on earth. For that life, he needs clothes, food and utensils, and the family of the dead man never fail to put these in a box above the grave. There is no idea of reward or punishment in the future life; neither does the *kalading* return to earth in any other form. The dead are not worshiped, and aside from the one *layog*—described later—no ceremonies or offerings are made after the funeral.

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[4] Gongs of copper.

[5] *Blumea balsamifera* DC.

Magic is known and practiced by many of the people. Strange dances and songs sung under a house can bring illness to its occupants. Some article of clothing belonging to the victim is put in a section of bamboo and placed near the fire to give him fever. Any article just handled by an enemy, or the dust of his foot prints when covered with poison, will bring him sickness or death. The folk-tales abound with stories of heroes who could call on the power of their head-axes, shields, or betel-nuts to transport them from place to place in an instant, to transform them into birds and animals, and to bring dead men to life. Many methods are used to detect a person practicing magic or doing wrong. The most general is to place an egg on the edge of a bolo or split bamboo, then ask the question. If the answer is "Yes," the egg will balance; otherwise it will fall. The top of a jar or the *peling* belonging to a medium is suspended by a cord and the question put: if the answer is "Yes," the article will swing, otherwise it will remain quiet.

BIRTHS AND MARRIAGES.

Children are much desired by the Tinggian, and every precaution is taken to guard the child from evil spirits. About the time a birth is expected, two or three mediums are summoned. A mat is placed in the middle of the floor and the spirit offerings are placed on it. Near the door a pig is tied and over this the mediums make *deam*. When they have finished, one of them pours water in the pig's ear, "so that as it shakes the water out, so may the evil spirits be thrown from the room." An old man cuts open the body of the live pig and thrusting in his hand he draws out the still palpitating heart which he gives to the medium. With this she strokes the abdomen of the expectant woman, so that the birth may be easy, and also as a protection against all evil. The slaughtered animal is soon prepared for food and the friends of the family eat and drink. When the meal is finished, the mediums begin to call the spirits, several of whom will come. One of these *anitos* acting for all the others makes *gepas* (the division) with an old man. The medium who is now possessed by the spirit puts a blanket called *enalson* over her shoulders; a head-ax is given to her and another to the old man. A pig is brought in, and to its head and tail is tied a narrow strip of cloth. After much debating the middle of the pig is decided upon and each seizes a leg with the left hand. The animal is raised from the floor and with the axes in their right hands they cut it in two. In this way the mortals pay the spirits for their share in the child and henceforth they have no claim on it. The women bring *basi* and the spirit drinks with the old man to cement the friendship. Other spirits are summoned until nightfall.

When the delivery takes place, the mother is attended by one or two women who knead the abdomen and assist in the removal of the child. The afterbirth is put in a jar and is intrusted to an old man who must exercise the greatest care in his mission and in his choice of a place for its disposal. Should he squint while the jar is in his keeping, the child will be thus affected. A book or letter inserted in the jar will cause the child to be very wise; while a few leaves of bamboo make the child grow like that lusty plant. If the afterbirth is hung in a tree near the trail, the infant will not be afraid; if hung in the jungle, he may fear men, but will become an excellent hunter. Often the river is chosen or the jar is buried: the former will result in an excellent swimmer and fisherman; but it is ill-fortune for the baby if the pot is put in the ground, for he will be afraid to climb a tree or to ascend a mountain.

Very soon after birth the child is washed and placed on an inverted rice winnower and an old man or woman gives it its name. The winnower is raised a few inches above the floor and the woman asks the child its name, then drops the winnower. Again she raises it, pronounces the name, and drops it. A third time it is raised and the child is advised to be obedient and industrious; a third time it falls, and the naming is complete. A Tinggian child is always named after a dead ancestor; often it receives two names, one of a relative on the father's and one on the mother's side. A third name, that of the day or month or one commemorating some occurrence at the birth, is frequently given.

Marriages are contracted for very young children. When the youth's parents have decided on a suitable girl, they send a relative who is able to "talk much and well" to broach the subject to the maiden's people. It is then his duty to explain the many desirable qualities of the youth and his family and to get consent for the union. If the suit is favored, a bead is fastened on the girl's wrist, and arrangements are made for the *pakalon*. This is a function to which the friends of the contracting parties are invited; food and *basi* are prepared and on the appointed day the townspeople and guests from neighboring villages come in numbers. The relatives form a circle to talk over the price which the girl should bring, and after a discussion often lasting nearly an entire day, a list is prepared. The payment usually consists of horses, carabaos, jars, blankets and a small amount of money. A portion of this is paid on the day of *pakalon* and is distributed to the girl's parents and relatives; but the balance is often left unpaid until the man's death. However, no division of his property can be made until the marriage agreement is paid in full. The children usually receive the unpaid portion of the marriage gift, as well as all the property possessed by the father at his death; if there are no direct heirs, the wife's relatives receive the balance due on the marriage list, while the man's relatives receive the remainder of his property. The completion of the list is the signal for great merriment; *basi* circulates freely; the men sing *daleng* and *tadek* is danced far into the night. The music for this dance is made with three *gansas* and a drum. The *gansas* are pressed against the thighs of the players who kneel on the ground. Two of the coppers are beaten with a stick and the palm of the hand, while the third is played by the hands alone. The stick or left hand gives the initial beat which is followed by three rapid strokes with the right palm. A man and a woman enter the circle each holding a cloth about the size of a *dingwa*. The man extends his cloth toward the woman and bringing it suddenly down causes it to snap, which is the signal to begin. With almost imperceptible movement of the feet and toes and a bending at the knees, he approaches the woman, who in a like manner goes toward him. They pass and continue until at a distance about equal to the start, when they again turn and pass. Occasionally the man will take a few rapid steps toward the woman with exaggerated high knee action and much stamping of the feet, or he will dance backward a few steps. At times the cloth is held at arm's length in front or at the side; again it is wrapped about the waist, the woman always following the actions of the man. At last they meet: the man extends his hand, the woman does likewise, but instead of taking his, she moves her own in a circle about his, avoiding contact. Again they dance away only returning to repeat the performance. Finally she accepts the proffered hand, the head man brings *basi* for the couple to drink and the dance is over. The man sometimes ends the dance by the sharp snapping of his cloth, or by putting it on his extended arms and dancing toward the woman, who places her cloth upon his.

After the *pakalon* the children stay with their parents until they are old enough to live together. The age for the final ceremony depends entirely on the wealth of the boy's family. If he is able to care for the girl, the marriage often takes place before either of the children reach puberty: in case the boy must earn a living, the marriage may not be consummated until he is eighteen or nineteen years of age.

When the time for the ceremony to be completed has arrived, the boy goes in company at night to the girl's house. In place of the customary bolo, he wears a head-ax, but he is the only one so armed. He carries a valuable jar which he gives to his parents-in-law; and from that time on he must not call them nor any near relative of the girl by name, or he will have boils and the first child born will be crazy. He also presents them with ten pesos which is part of the agreed price. The girl's people have prepared a dish of rice and a shell cup of water, and the couple sit on opposite sides of these on the floor. The boy's mother puts two beads into the water and each of the couple take a drink from it. Great care is taken not to shake the cup, or they will get dizzy, and when old their heads and hands will shake. The two beads always go to the bottom of the cup together, and so the couple will not part; the cold water keeps them from getting angry. After they have drunk, each takes a handful of rice and squeezes it firmly into a ball. The girl drops hers through the bamboo floor as an offering to the spirits, but the boy tosses his into the air. If the ball breaks, it is a bad sign and the couple are apt to part. Often the marriage is deferred and tried again a few days later; repeated breaking of the ball would cause an annulment of the agreement. If the ball rolls, it is not a good sign as they may be unfaithful. Should it go under the boxes and jars, their children will die. If the ball remains intact and does not roll, the signs are most favorable and all will go well. If at any time during the proceedings a thing should fall or be broken in the house, the ceremony is stopped at once; to proceed that night is to court trouble, but a few days later they will try again. The guests now depart. No food nor *basi* is given nor is there any kind of a celebration. For two days the couple are subject to strict taboos, a violation of which would cause disaster for themselves or their children. The month following the marriage they live at the girl's house, after which they go to the home prepared by the boy or to that of his parents. They are accompanied by the groom's mother and go very early in the morning so that the birds can not give a bad sign. The girl carries her mat, blankets, and two pillows with her. Before she can eat of her husband's rice, he must give her a string of beads or she will be sick: she may not open his rice granary until a like present has been given or the spirit of the granary will make her blind.

If at any time the relatives of the girl have reason to doubt the husband's affection they may make *nagkakalonan.* They carry a pig, jar and a number of baskets to the house and spread them on the floor. In order to prove his love, the man must exchange money and presents for them, after which a pig is killed and eaten by the guests. Should the old men decide that there was no cause for doubt, the relatives must pay the cost of the gathering and the husband does not exchange anything with them. No trace of the clan system is to be found, but marriage is prohibited between blood relatives.

FUNERALS.

The death of a child is followed by little or no demonstration, but when an adult has expired elaborate ceremonies follow. The corpse is dressed in good clothes and is placed in a death chair. Before it two or three old women sit both day and night to wail and guard against evil spirits who may wish to harm the dead, or his spouse. The bereaved dons old clothes, and with a white blanket thrown over her,[6] sits in one corner of the room behind a barricade of pillows. Thus placed she is more easily protected from evil *anitos* who are sure to use every device to take her life as well. Above the corpse a cord is stretched and on it blankets and other gifts are placed so that the spirit of the dead man may carry them with him to his ancestors in Maglawa. Offerings of *basi,* food, chickens and pigs are made to the different spirits who always attend a funeral with evil intent. Other animals are slaughtered for food and until sunset of the succeeding day the friends eat and wail. There is neither music, singing, nor dancing. Burial is under the house. It is customary to reopen the grave of the dead man's ancestors and there to inter the body. Just at sunset the grave is in readiness (this is the common, but not universal time for burial). The greatest excitement prevails as the medium sits down in front of the body and summons the spirit. As it enters her body she falls back in a faint, in which condition she is allowed to remain for a moment; then fire and water are brought; the spirit is driven away and she gives the last messages to the family. A mat is wrapped tightly about the corpse and four men bear it from the house to the *balaoa.* It is rested near the spirit structure for an instant on its way to the grave, for *Kaboneyan* told the first Tinggians that unless they did that the spirit would be poor in *Maglawa* and unable to build *balaoa.*

That night the men gather and sing *Sangsanget,* a song in which they tell of the dead man, encourage the widow and pray for the welfare of the family. All that night and the succeeding nine days and nights a fire is kept burning near the grave to keep away the evil spirit, *Ebwa.*

The morning after the burial the relatives construct a bamboo box and place in it the clothes, utensils and food which the spirit will need in the future life. This is hung above the grave and the whole is surrounded by a bamboo fence.

Soon after this, the blood and oil ceremony is made, for until the wife and relatives have been anointed with blood and oil, they may not eat of anything except corn, neither may they swing their arms nor touch anything bloody, and all work is tabooed.

The spouse of the dead continues to wear old clothes until the *layog* is made. This ceremony, which is celebrated in six months or a year, makes the family forget their sorrow and also shows their respect for the dead. Invitations are sent to the neighboring towns and on the appointed day a great crowd has gathered. A medium goes to the guardian stones of the village and there offers rice mixed with blood to the spirits, oils the stones, and after dancing *tadek,* returns to the gathering. Rice, pigs, cows or carabaos are prepared for food, while *basi* flows freely. A chair containing the clothes of the deceased and offerings for his spirit is placed near the house ladder. In the yard, four crossed spears form the framework on which a shield rests and on this are beads, food, and clothes—offerings for the spirits. According to the wealth of the family, the guests for one or two days remain eating, singing, dancing or indulging in games. The mat of the dead person which, until now, has remained spread out in the house is rolled up, the doors and windows which have been kept closed since the funeral are thrown open, and the family don their good clothes and make merry with the guests.

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[6] The procedure is the same for men or women.

CONCLUSION.

This brief sketch of some of the more important incidents in the life of the Tinggian can not well be closed without a word concerning his relation to his nearest neighbor, the Ilokano. The writer was early impressed by the similarity between the Ilokano of the outlying barrios and the Tinggian. As the various dialects were studied, it was strikingly evident that we were dealing with primitive Ilokano. The work in physical anthropology yielded much the same results. The people of isolated Christian barrios corresponded almost exactly to their wild neighbors, while those in the larger towns showed the influence of intermarriage with other peoples. In developing the genealogical tables it soon became evident that the non-Christians had many relatives in the civilized communities, and further search revealed the fact that many of the leading Ilokano families of Bangued, and through them of Vigan, were only four or five generations removed from the Tinggians. The Ilokano still retains many of the customs and beliefs of the older generations, and a study of these shows many of them to be almost identical with those of the Tinggian.

What the future may have in store for this people must be determined largely by the influence wielded by the schools over the younger generation. In those towns where the Ilokano influence has been the strongest, the Tinggian has been undergoing a certain amount of degeneration physically, industrially and morally. By nature he is industrious and if his energies can be directed without his acquiring the vices of his "civilized" neighbors he will become a useful member of the community. The first great step toward this end was taken when Commissioner Worcester succeeded in establishing an industrial school for Tinggian boys in Lagangilang (Abra).

ILLUSTRATIONS.

PLATE I.

FIG. 1. Lagangilang, Abra.
2. Boy on a carabao.

PLATE II.

FIG. 1. Transporting logs and bamboos.
2. Building a house.

PLATE III.

FIG. 1. Inclosure for drying rice; granaries in the background.
2. Woman pounding rice.

PLATE IV.

FIG. 1. Preparing tobacco for curing.
2. Making pots.

PLATE V.

FIG. 1. Tinggian cane press.
2. The sirup vats; basi making.

PLATE VI.

FIG. 1. Medium making *deam* before the guardian stones.
2. Building the spirit house, *Tangpap*.

PLATE VII.

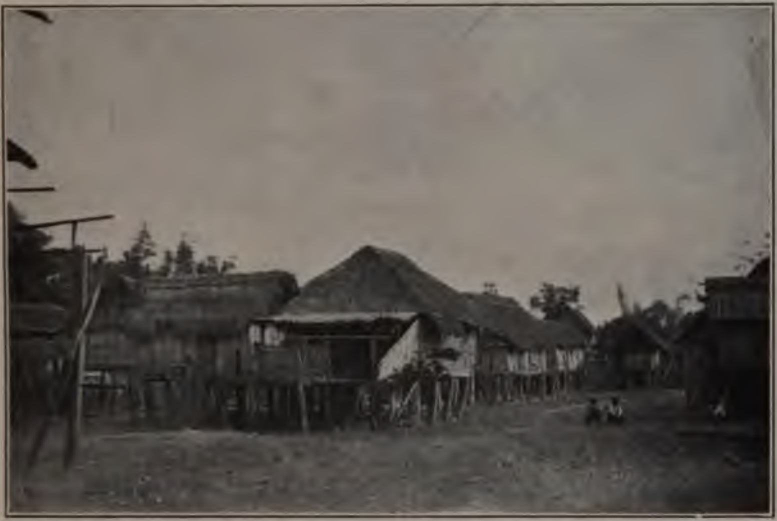
FIG. 1. Mediums summoning the spirits.
2. The spirit talking to mortals.

PLATE VIII.

FIG. 1. Family group.
2. Portrait of Tinggian.

PLATE IX.

FIG. 1. Portrait of Tinggian.
2. Portrait of Tinggian.
3. Portrait of Tinggian.
4. Portrait of Tinggian.



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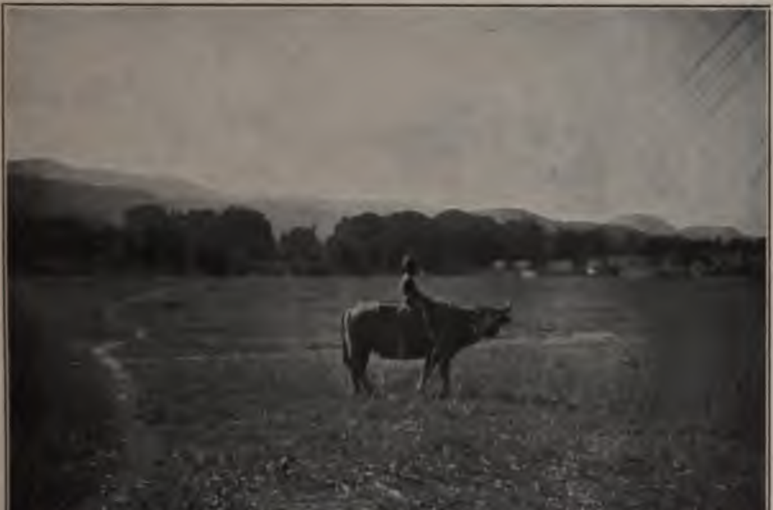

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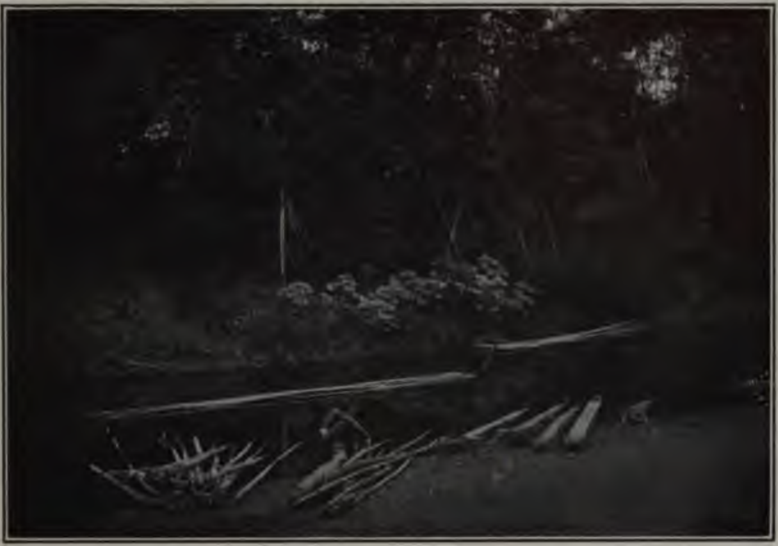

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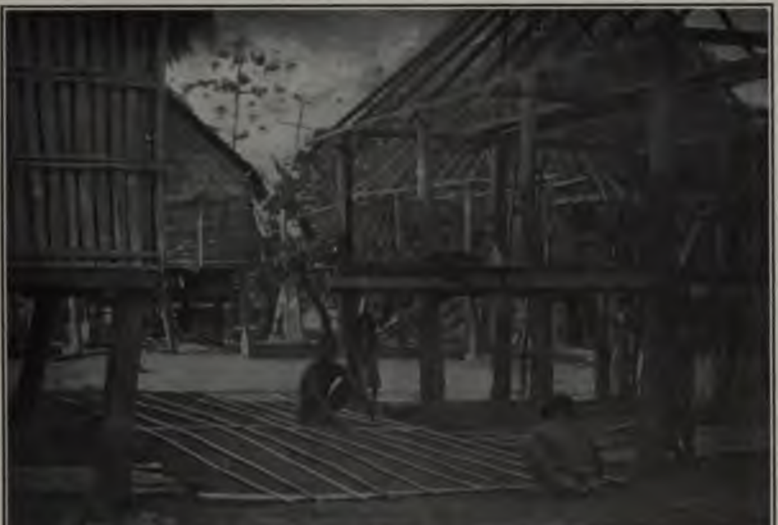

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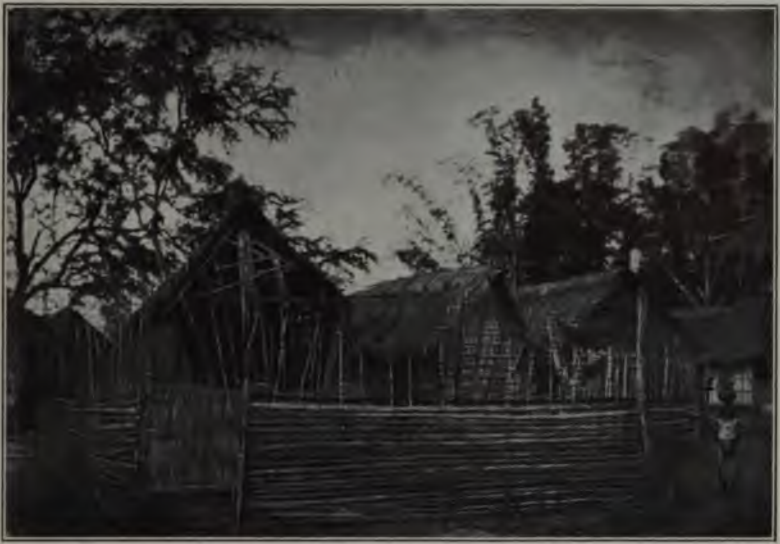

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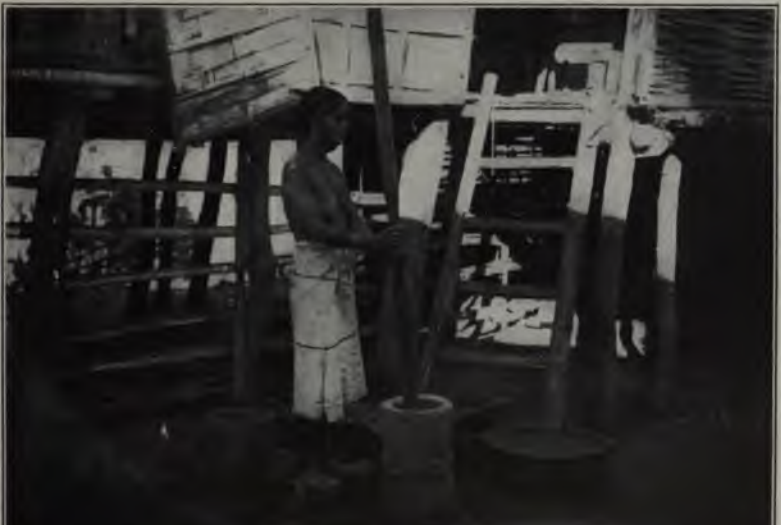

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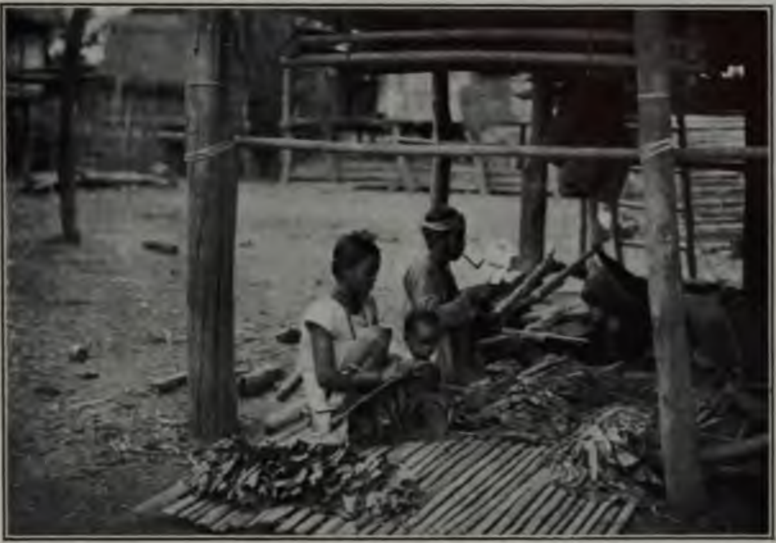

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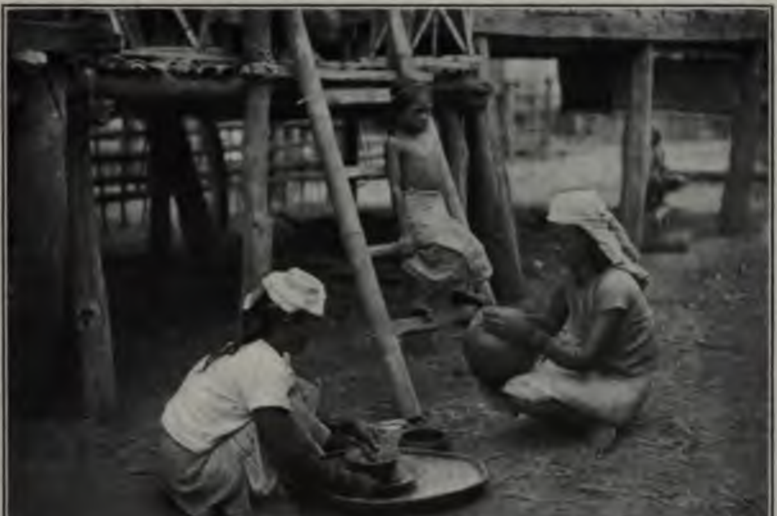

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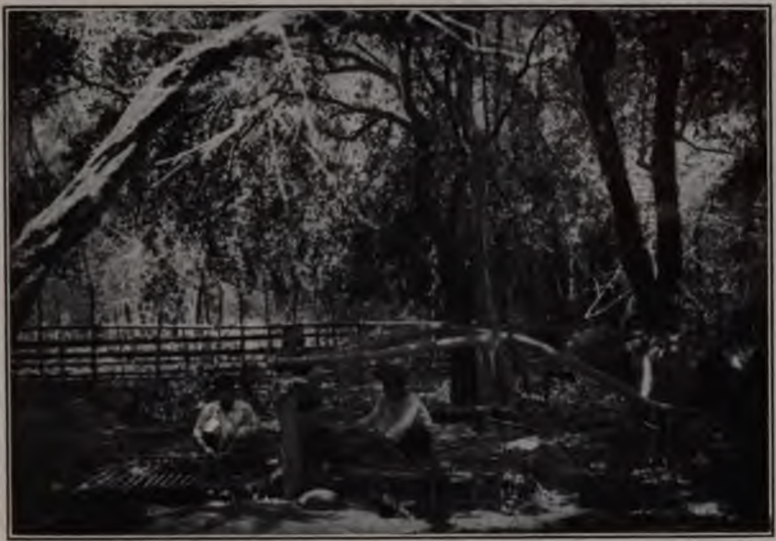

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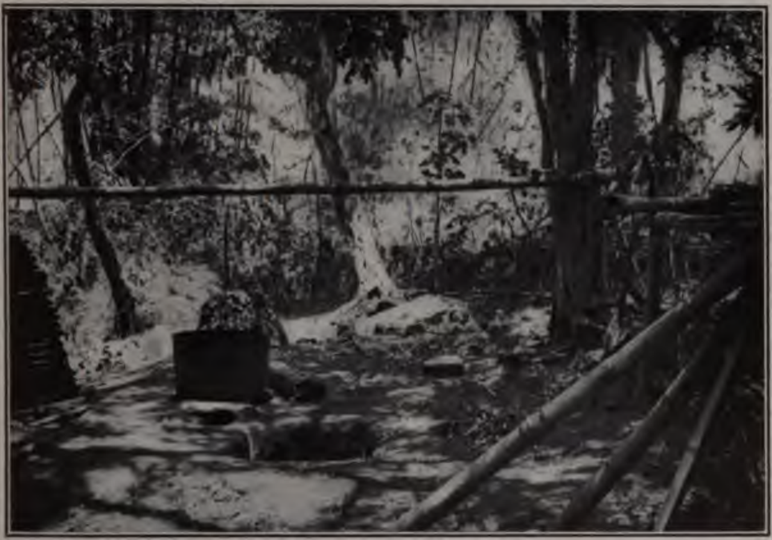

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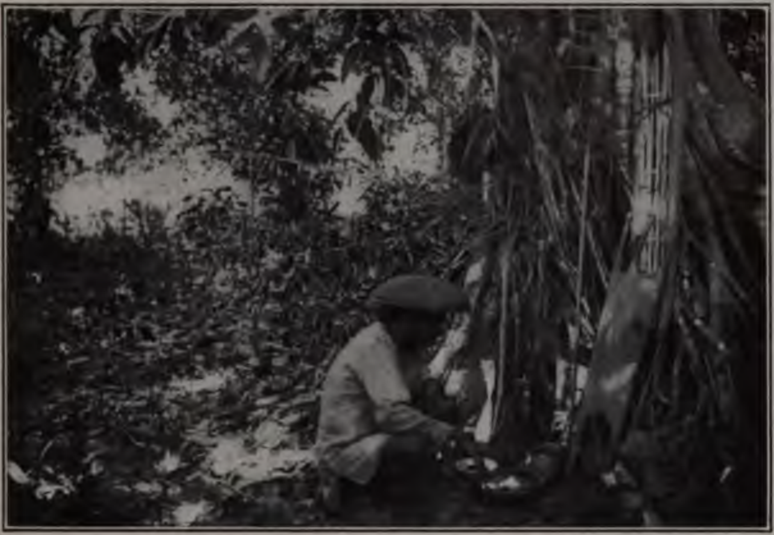

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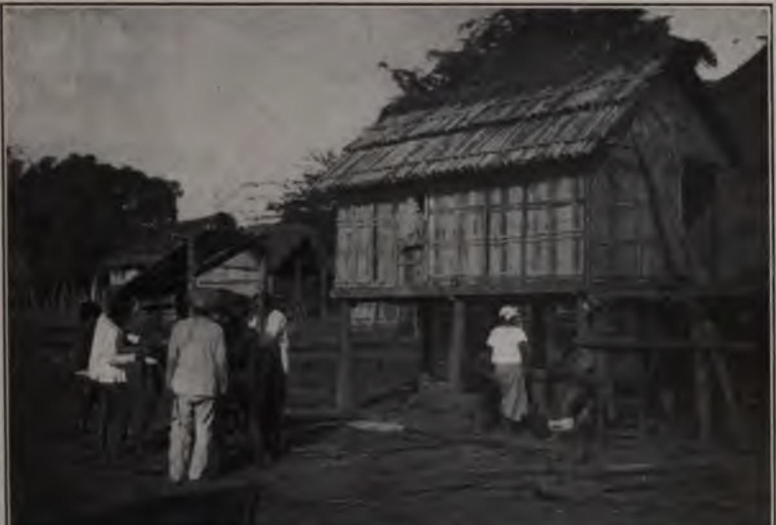

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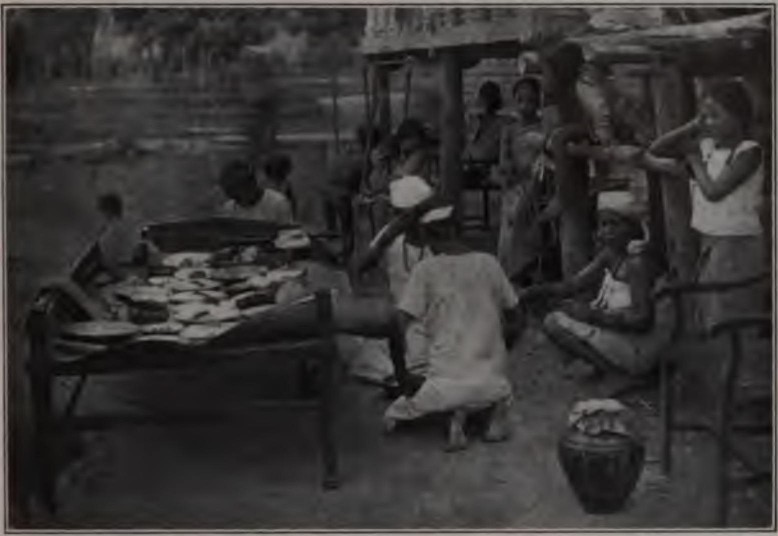

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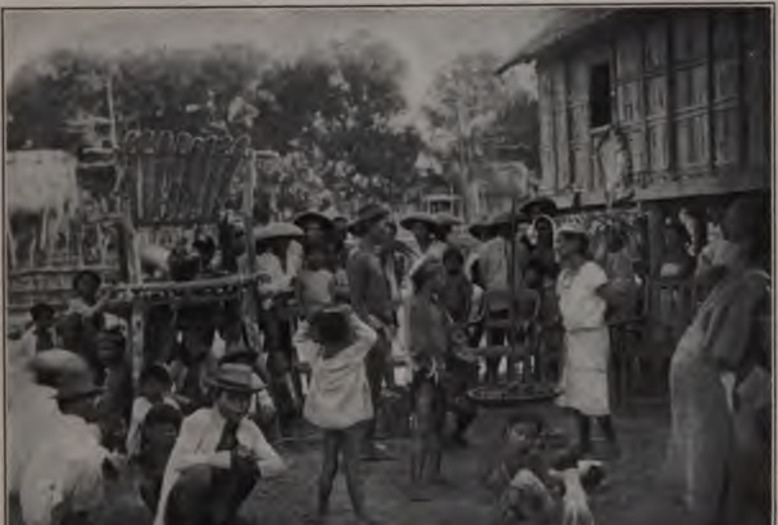

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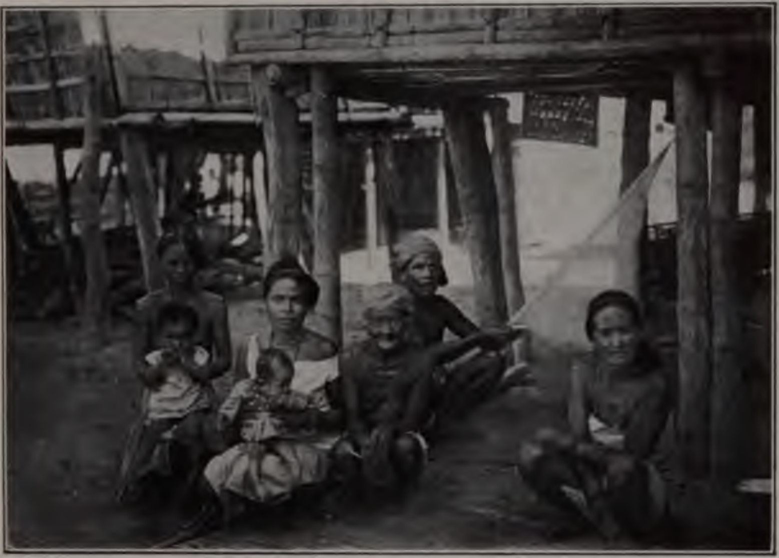

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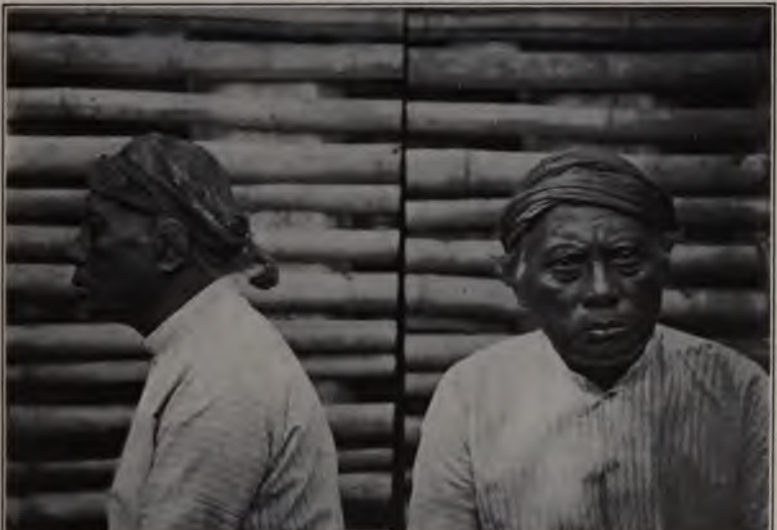

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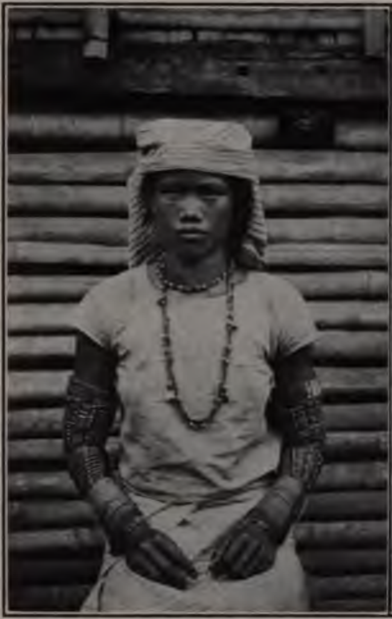

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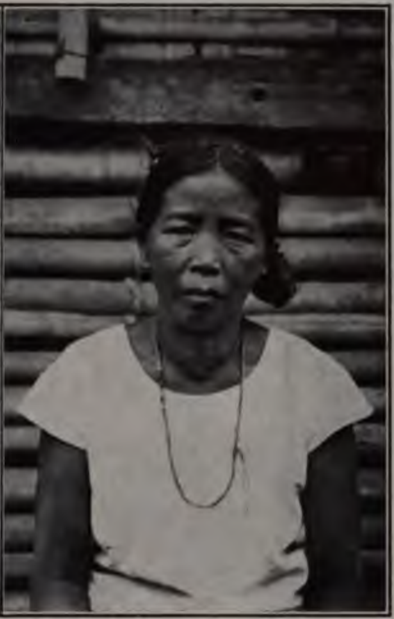

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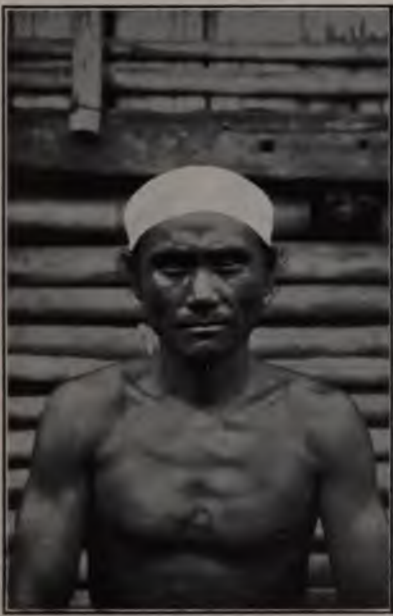

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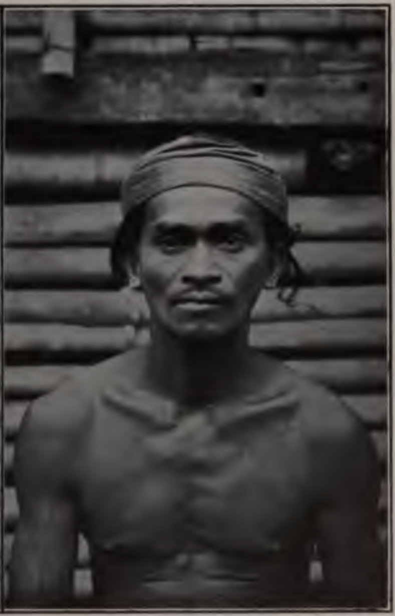

FIG. 4.

PLATE IX.

A THEORY OF HEREDITY TO EXPLAIN THE TYPES OF THE WHITE RACE IN NORTH AMERICA.

By Robert Bennett Bean.[1]

(From the Anatomical Laboratory, Philippine Medical School, Manila, P. I.)

The classification of the types of man is a stumbling block for anthropologists. The basis of such a classification varies with different authors and few agree as to what constitutes a type, a race, a stock, or a family of men. No attempt is made in this paper to define these different terms, but the word type is used to represent a composite entity that is homogeneous in a group of individuals.

ARRANGEMENT OF DATA.

The results recorded in this paper are based on measurements made on more than 1,000 students (923 boys, 116 girls) at the University of Michigan in 1905, 1906 and 1907, all of whom with few exceptions were members of the freshman class.

The physical attributes fall naturally into several groups, such as cephalic index, pigmentation, height, etc., and the types readily assemble with these attributes as limitations. There are four primary types, four secondary, and five blended ones.

CLASSIFICATION OF TYPES.

The most prevalent type is termed the "Northern" throughout this paper, because it originally appeared in northern Europe, now predominates there and is designated as Northern by many authors, although it is identical with the Cymric race of Broca, the *Homo Europeus* of Lapouge, and the Teutonic (Germanic) or race of the "row graves." This type is tall, fair haired, light eyed and dolichocephalic, and it occurs in 18 per cent of the boys and 22 per cent of the girls.

The second of the primary types is designated the Iberian (Pl. I), because of its evident derivation from the Iberian of Great Britain and Europe. This is the Mediterranean race of Sergi, the southern Europe or *Homo meridionalis* of Ripley and Lapouge; in fine, the Hamitic stock

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[1] Read at the Fifth Annual Meeting of the Philippine Islands Medical Association, Manila, February 28, 1908.

that spread in earlier times over Africa, Asia and Europe and filled the "long barrows" of Britain. The Iberian of America is above the average in stature, very dark haired and dark eyed, and dolichocephalic, and the type appears in 16 per cent of the boys and 18 per cent of the girls.

The third primary type is that of the Celt of Broca, the Middle European, Rhetian, Celto-Slav, Ligurian or Celto-Ligurian of certain anthropologists, the *Homo alpinus* of others. The name Alpine is used in the present article. The physical characteristics are medium height, moderate pigmentation (brown hair and eyes), and brachycephaly, and the type is found in 10 per cent of the boys and in 10 per cent of the girls.

These three types represent three primary elements in the population of Europe and are believed by many to be the three primitive white stocks, but there is an additional type, which, with its two secondary types, is distinct and characteristic of a large element of the American population. This is the broadheaded Saxon of Beddoe, and the Oriental or eastern European of Deniker. The present inhabitants of northeastern Europe and middle western Asia conform to this type, which is above medium height, has fair hair and eyes and is brachycephalic, occurring in 9 per cent of the boys and in 9 per cent of the girls. It is hereafter referred to in this article as Saxon.

The two secondary types closely associated physically with the Saxon are the Celtic and Vistulian, the former being like an extreme Saxon in large proportions, the latter resembling the same type in the opposite direction, being the smallest physically of all the types. In Great Britain the Celt (Pl. II) is the muscular, tawny gaint of history, the Kelt of English writers, the prehistoric man of the "round barrows," with a height exceeding that of the Northern type, which is noted for this feature, a cephalic index greater than that of any other, and very fair hair and light eyes. This type occurs in 2 per cent of the boys and 2 per cent of the girls.

The Vistulian is Deniker's type of that name, so called from its apparent predominance along the Vistula River. This type is very short in stature, has fair hair and light eyes, is mesocephalic, and is found in 4 per cent of the boys and 4 per cent of the girls.

These three types, Saxon, Celtic and Vistulian, may be variations of one original, but there are distinctions such as height, cephalic index, class standing, etc., that render them clearly separate and different at the present time.

The two remaining secondary types, the Littoral and Adriatic, bear the same relation to the Iberian and the Alpine respectively as the Celtic bears to the Saxon, and one might select from the Iberian and Alpine each a type bearing the same relation to them that the Vistulian bears to the Saxon. In like manner, the Northern type might be subdivided into three—an extremely large, an extremely small, and an intermediate one. Each of the four primary types would then be resolved into three, but the distinctions are slight in all except the Celtic, Vistulian, Littoral, and Adriatic, and these four last named are described and located in Europe in the recent work of Deniker, so there is justification in the grouping given above. Whatever may be said in regard to the secondary types, no just objection can be made to the four primary ones.

The Littoral type (Pl. III) corresponds closely with the "Mediterranean Race" of Houzé, the Cro-Magnon of some authors, and the Littoral or Atlanto-Mediterranean of Deniker, and usually appears in Europe not more than 120 to 150 miles from the coast. The type is *very* tall, has *very* dark hair and eyes, is mesocephalic, and occurs in 3 per cent of the boys and 5 per cent of the girls.

The final secondary type is Deniker's Adriatic or Dinaric, tall, dark and brachycephalic, and it may belong to the Lorraine race of Collignon. It is present in only 2 per cent of the boys and not at all among the girls.

The blended types are apparently mixtures of two or more of the primary or secondary ones. Blend No. 1, or Celt-Iberian (Pl. IV), which is above the average in height, has the largest chest of all, intensely black hair, light blue or gray eyes, and is mesocephalic. This is present in 8 per cent of the boys and in 3 per cent of the girls, representing a well known so-called "Irish" element in America, but found there also in other than the Irish population. It is probably a blend of the primitive Iberian of the "long barrows" in the British Isles and the later arrivals, or Celts, of the "round barrows."

The individuals of Blend No. 2, or Northern-Iberian, are very tall with dark hair and light eyes (the latter often green) and are extremely dolichocephalic, with a cephalic index lower than any other type. This is probably a blend of the Iberian and Northern type, and occurs in 5.5 per cent of the boys and in none of the girls.

The third blended type, Blend No. 3, is probably largely Alpine with an admixture of Northern, and might be called Northern-Alpine. It is of medium height, mesocephalic, with light brown eyes and blonde hair, and is found in 4 per cent of the boys and in 3 per cent of the girls.

Blend No. 4, is very rare and is largely Iberian, or Saxon-Iberian. It is below medium height, has dark hair and light eyes, is brachycephalic, and occurs in 1 per cent of the boys and 4 per cent of the girls.

Blend No. 5 is a conglomerate with a preponderance of Saxon elements, but also with evidences of Iberian, Northern and Alpine and may be considered a composite American type, toward which all others tend. It is of medium height or slightly taller, with light brown or sandy hair, eyes of all the lighter shades, namely, blue, gray, green, light brown or hazel, and a mesocephaly characteristic of the English people. It is present in 13 per cent of the boys and in 20 per cent of the girls.

In addition to these, 15 Jews and 7 mulattoes were included in my study at the University of Michigan.

FEMININE TYPES.

Although only 116 girls were measured, the types are so nearly like those of the boys, with a reduction in height and an increase in cephalic index, that a few words regarding sexual affiliations and differences may not be out of place.

One most striking result of a comparison of boys and girls by type is that the mean has a greater range of variation among the girls than among the boys. The differences between the means of the types is greater for girls than for boys, except in height, where the boys have greater variability.

TABLE I.—*Differences of type means.*

Sex.	Weight.	Height.	Chest.	Pigment.	Head.			Cephalic index.	Brain weight.	Class standing.
					Length.	Breadth.	Height.			
Girls	18.2	13.7	10.0	66.0	1.6	0.99	0.60	7.3	100	20.0
Boys	10.7	15.6	3.8	53.4	0.7	0.65	0.41	5.6	59	13.8

This may have a broad significance, especially when it is known that the variability of the girls is in the direction toward the supposed precursor, the male tending toward a common mean, the female toward the primary stock. This would reconcile the conflicting views of many biologists with Pearson's school of biometricians, the first claiming man to be more variable than woman, the second, the opposite. Pearson and his followers have made observations by "random sampling" and, working on the mean of such samples regardless of type or individual, have necessarily overlooked that which a more detailed and intricate study reveals. Variability is indeed greater in a "random sample" of women than in one of men, but it may be true only because women tend to remain true to the original type, while men vary toward a common mean. If further research corroborates this conclusion, a factor of prime importance is added to the principles of heredity. This is one of the many indications of the postulate that heredity is a persistance of type with modifications, and the modifications may be greater among men who must become habituated to surroundings, while persistance of type is more evident in women who are more or less shielded and become modified more slowly. There seems to be a sexual difference in intellect, the Iberian being the male leader and the Saxon the female leader, while the Alpine is apparently not so vigorous as the others either physically or mentally. The above observations are suggestive, not final.

To summarize the feminine types, it may be said that the height, weight, chest girth and head size are less for the girls than for the boys, while the class standing and the cephalic index are greater. The feminine types correspond fairly well to the masculine ones of the same kind, with minor differences.

The fact that the same types can be collected from a hundred girls as from a thousand boys, in nearly the same relative proportion as to number and with similar physical differences, speaks well for the types selected as representing realities. Head size, particularly frontal width and class standing, are correlated, but cephalic index and class standing show no correlation.

There is a slight indication that the girls may be more nearly like the aboriginal types than the boys, because the blonde girls are fairer and the brunette girls are darker; the height of the girls is relatively nearer that of the primitive types than is the height of the boys; the chest girth of the girls is also closer to the original. The cephalic index, head length and width, places the long-headed girls relatively nearer to dolichocephaly than the long-headed boys, and the broad-headed girls are decidedly more brachycephalic than the broad-headed boys.

The head shape of the girls is shorter, broader and higher, with prominent frontal and occipital regions, due partly to small brow ridges and small occipital protuberances. This gives a square, vertical forehead similar to those of the Iberian boys, the shape of which is due to the same factors.

TYPE HEREDITY.

A tentative scheme of heredity, or of the processes that are transforming the physical characters of man, is formulated for the first time in this paper, in order to throw light upon the existing types of the white people and to assist in tracing their origins, as well as to determine some of the forces at work in shaping the formation of new types. The scheme embodies the principles of determinate variation, alternate variation and discontinuous variation, and applies these principles in a practical way to explain type heredity in man. It is briefly as follows:

An original germ plasm contained all (?) the possibilities of life. Certain innate tendencies influenced by surrounding conditions caused variations from time to time (determinate variation) until a type became too differentiated and specialized (evolution) to exist, and perished (paleontology). The germ plasm persisted. Man is at present one of the differentiated and specialized living forms. Types of man have been produced favorable to the surrounding conditions (isolation), and the crossing of these types blends definite characters and again disengages them, each of the blended characters returning, more or less pure, in succeeding generations (alternate variation). After characters become highly specialized, losing some qualities and gaining others by a process of elimination and accretion, the crossing of types containing such highly specialized characters may unite apparently dormant qualities in each type and produce a new type unlike either of the original, this being called a mutation, a sport of reversion (discontinuous variation). Heredity then is like producing like, with modifications, or simply descent with variability.

Heredity has three factors, a determinant, a modifier, and a law of chance, and these three regulate variation, or heredity acting through environment.

The determinant, or the germ plasm, which has direct descent from the germ cell of one generation to that of the next, has its activities expounded by Weissmann, Galton, and Brooks, under the designation of Weissmann's theory of heredity.

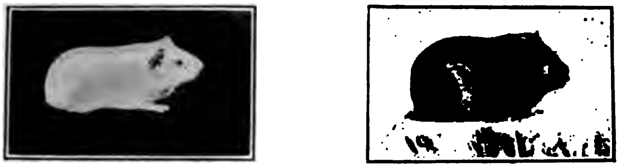
The modifier has been variously set forth as selection by Darwin, use and disuse by Lamarck, strength of parts by Roux, organic selection by Mark Baldwin, Osborne and Lloyd Morgan, and isolation and other factors by many other biologists.

The law of chance is Mendel's law, or that of alternate variation, as elaborated by Castle, Bateson and others and exemplified by the inheritance of male from female and vice versa, through the specificity of the accessory chromosome, as identified by Henking, McClung and Wilson, as well as by certain hereditary affections such as color blindness, peroneal atrophy, congenital cataract, hemophilia, alcaptonuria and other abnormal characters, like two joint digits, web fingers, etc. These usually show either dominant or recessive characteristics and are as a rule inherited by the male through the female, the latter not being affected.

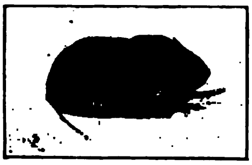
The law of chance is the law by which the determinant acts, and environment is the modifier.

Mutation, or fluctuating variability, may be explained as the action of the modifier on the determinant by accumulated and oft repeated variation in a definite direction (determinate variation), as represented by the paleontologic records of the horse; and then the unexpected crossing of long separated and specialized germ plasm or individual characters, gives rise to reversions, sports, or mutations. Continued intercrossing of differentiated characters, or specialized germ plasm, causes fluctuating variability. Determinate variation, fluctuating variability and mutation are processes illustrating the modifications of the determinate factor.

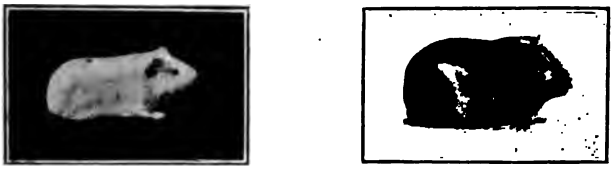
Mendelism represents the action of the two extremes of a single character when crossed, such as black and white hair, long and short hair, smooth and tufted hair, etc. In the first generation of such a cross the dominant factor obscures the recessive and all appear to be dominant, but in the next generation of a cross *inter se* the recessive factor reappears, and always in a definite proportion. When black and white guinea pigs are crossed the second generation is all black, but the third generation has three black and one white (fig. 1).



First generation.



Second generation.



(From Castle: Pop. Sci. Monthly.)

Third generation.

FIG. 1.—Effect of crossing white and black guinea pigs.

The white is pure and breeds true. Only one of the blacks will do this, however, because the other two are hybrids like the second generation. There is an equal distribution of both dominant and recessive elements, although the apparent relation is three dominant to one recessive. The distribution follows the law of chance as illustrated by H. H. Newman in his lectures at Ann Arbor on heredity, or by the use of colored discs. Put equal numbers of black and white strips of paper into a receptacle and draw out one in each hand noting each time what is produced, whether two white, two black, one white in the left hand, one black in the right, or one white in the right hand and one black in the left. An equal number of each of the four possibilities will result if this process is continued indefinitely. However, Mendelism represents something besides the law of chance, because the dominant obscures the recessive, and the law holds true for individual cases, while only in the ultimate result can the law of chance be tested. Mendelism may be the method of readjustment of individual characters when they are brought together by crossing after their extreme limit of variability has been reached.

Blending does not begin at once, but only after repeated crossing has taken place. This may be explained by the action of the chromosomes in the germ cells. When the ovum has rid itself of unnecessary chromosomes and has conjugated with the spermatozoön to regain the chromatic equilibrium of its kind (type), then all the hereditary powers that produce the individual are present. Whatever further development takes place is caused by the chromosomes acting through the environment. When the first few cell divisions take place there may be little influence from environment, but the greater the number of cells, that is, the further away they are from the original one, the greater is the influence of environment and the greater becomes the differentiation of the individual cells. During a long series of generations of an individual species (type), the changes produced even in the germ cells by division, growth and nutrition must be so great and the ultimate germ cell so far removed from the original one that the supposition of its unaltered condition is untenable, and this is true without considering the manifold influences on the germ plasm during the life of each individual. A germ cell may separate itself from the other cells almost at the beginning of the segmentation of the ovum (fig. 2), and in this way carry on directly

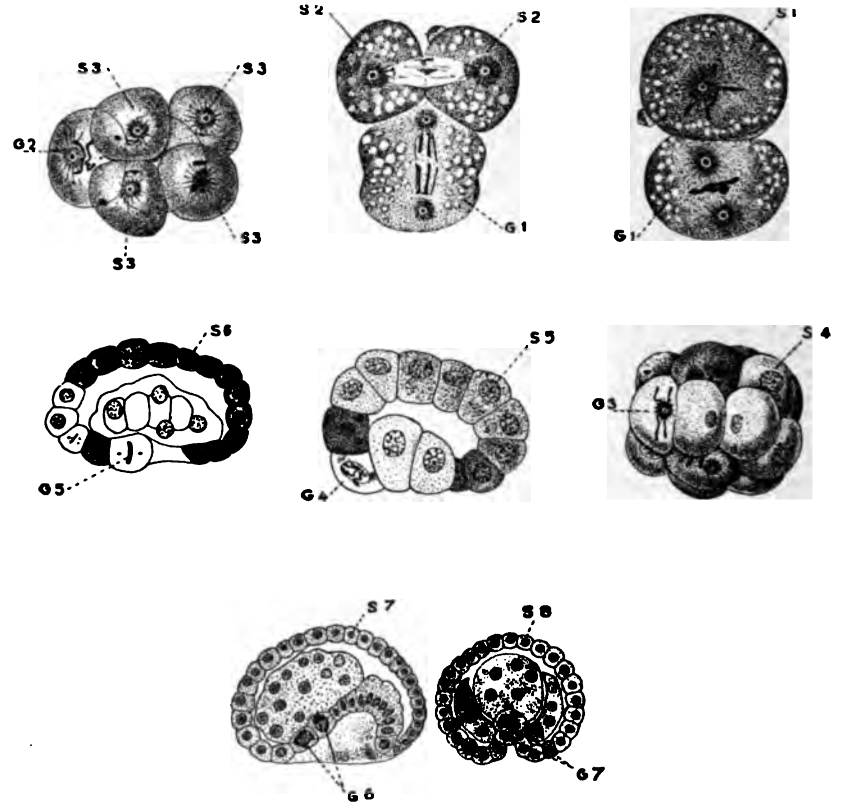


FIG. 2.- Segregation of the sex cells in the segmentations of the ovum after fertilization. *Ascaris megalocephala* var. *univalens*. (Adapted from Buck's Reference Handbook of the Medical Sciences, 1902, **4**, 650. After Boveri.)

The germ plasm divides by doubling division (growing in bulk and dividing) so that each resulting mass is precisely like the other. One of these may divide repeatedly, always doubling, and remains unaltered germ plasm (G 1–2–3–4–5–6–7) going to that part of the individual from which new organisms arise (ovary in woman, testicle in man.) The germ plasm is thus handed on directly from generation to generation.

The second portion of the germ plasm (somatic cell) (S 1–2–3–4–5–6–7–8) undergoes differentiation division, and controls the building of the individual.

to the succeeding generation the chromosomes of the two parents, but the physical and chemical impossibility of the single cell containing all the necessary determinants for all possible forms of life is readily perceived. The germ plasm may be acted upon by environment, as would be indicated by the effect of intoxicants (in a broad sense such intoxicants as alcohol, bacterial toxins, internal secretions, diathesis, etc.), in the hereditary transmission of tendencies and in producing monsters, epileptics, etc. Therefore, the immortality and immutability of the germ plasm must be acknowledged to be inconceivable.

Adami's scheme, which is a combination of Ehrlich's side chain theory and Mendelian heredity, is a good graphic representation of the chromatic relations of the germ cells. Each germ cell has a central ring with side chains to which are linked affinities (fig. 4). The chromosomes represent the side chains. The central ring does not alter, but the side chains may. Sex cells or germ cells contain the original side chain unaltered. Liver cells, muscle cells, etc., contain many side chains.

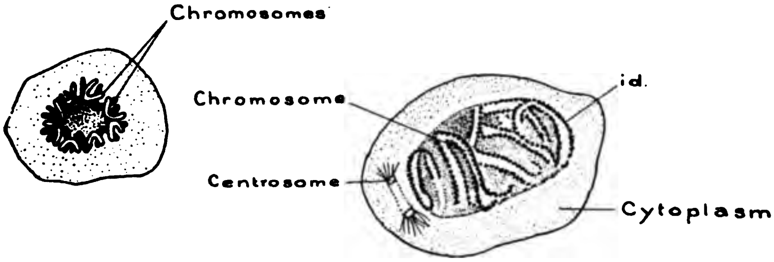


FIG. 3.—Weissmann conceives that the chromosomes which produce an individual consist of many *"ids"* each of which contains all the possibilities of a new organism. The *"ids"* possess an historic architecture that has been slowly elaborated during the multitudinous series of generations that stretch backward in time from every living individual. Each *"id"* consists of determinants which represent the various parts of the individual that may undergo variation, and each determinant is composed of biophores which enter the cells and direct their vital activity.

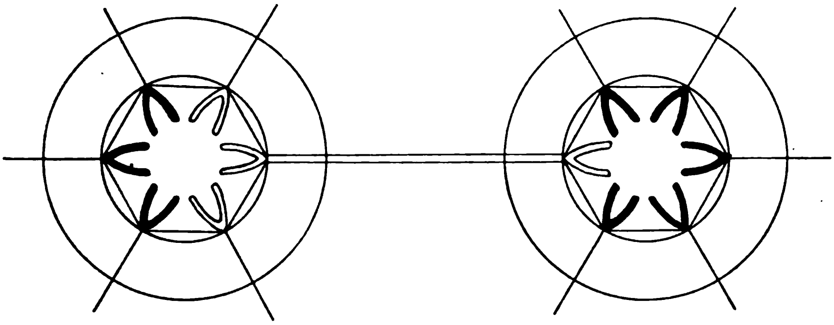


FIG. 4.—Adami considers that the germ cells are similar in nature to the benzene ring. The chromosomes represent the side chains that link together affinities. Like chromosomes attract like. Unlike chromosomes repel each other, but may finally fuse after repeated contact through many generations.

Environment begins its action when cell division commences, the environment of each cell becoming different from that of its predecessor. In this way the side chains become changed and heredity is affected (fig. 5).

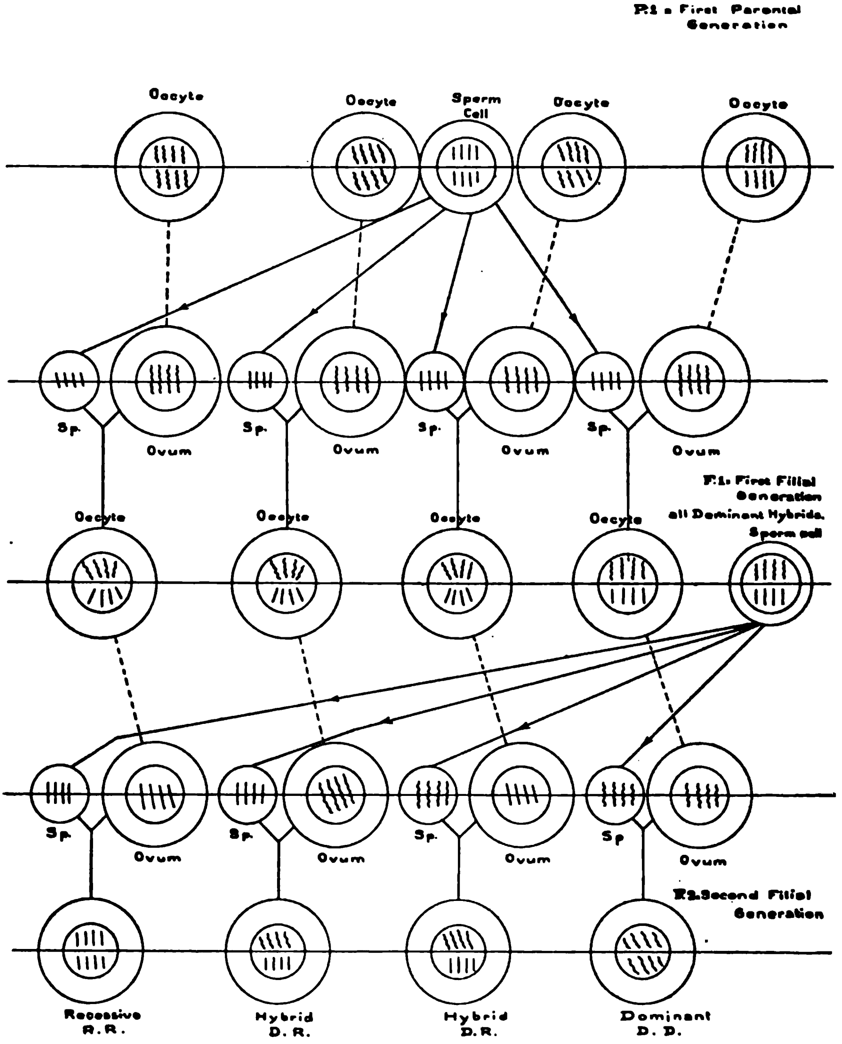


FIG. 5.—A single germ cell after fusion with another may be acted upon by environment, the struggle of parts, use and disuse, physical activity, organic selection, natural selection, isolation, or any other influence, so that after many generations have passed each individual developed from the original germ cell will have become differentiated and specialized. If the influences have been opposite in nature on two groups of individuals in different localities, extreme variations in opposite directions may have taken place. When these variations are crossed, there is an exhibition of Mendel's laws as illustrated in the figure, for a period of time, with inbreeding, but finally there is fusion more or less complete. At some time in the course of fusion there are three types, the two original ones and a blend of the two. The ultimate result may be complete fusion with the formation of a perfect blend.

When each sperm cell or oöcyte of the first filial generation is a hybrid of mother and father, it gives rise to ova or spermatozoa by reduction division with a loss of one-half of its chromosomes, thus becoming like mother or father. Then it unites with a like or unlike cell of the opposite sex (ovum or sperm) and reproduces type according to Mendel's laws. This applies when the cross of two opposite extremes in one character takes place, as when blue eyes and brown eyes (Davenport), long and broad head or long and wide face are crossed (Boas), but not when this is the case with the two opposite extremes of other characters, such as ear length in rabbits. Blending ultimately manifests itself even in the most diverse characters that at first exhibit Mendel's law in all cross-mating. Castle has shown that repeated crossing for many generations alters apparently pure characters, so that black hair becomes contaminated with white and white with black, and although continual crossing has not been carried on further than this, there is reason to believe that ultimately the extremes will produce a perfect blend.

In any cross of extremes the chromosomes or side chains of the germ cells are in unstable equilibrium. In the next generation there is a rearrangement of the chromosomes in all possible combinations, giving a ratio of apparent dominant to recessive, of 3 to 1, 9 to 1, or 27 to 1, with one character, two characters, or three characters respectively. Continual crossing *inter se* enables the side chains or chromosomes to become accustomed to those of the opposite nature by continued union and disunion in the sex cells; the opposite qualities become reconciled, as it were, and blend slightly. This blend becomes more and more perfect and complete as generation succeeds generation.

It is to be supposed that when two distinct types of men come together and intermarry, there will be a conformity to Mendel's laws more or less complete for each character, depending upon the distinctness of the types; then a gradual alteration of each type in the direction of the other takes place until finally, if time and other circumstances permit, there is a perfected blend of the two. This has probably occurred in Australia, Tasmania, and other isolated regions, and is now going on in nearly all parts of the world.

Prehistoric Europe, Asia, and Africa were overrun by hordes of little people now generally known as Iberians, who settled the British Isles, the Atlantic coast and the Mediterranean basin almost to the exclusion of all others. The Iberians were short, slender, delicately molded individuals with coal-black hair and eyes, a tan complexion and a very long, narrow, high head represented to-day by the most characteristic Spanish type. (Pls. I, VI, etc.) This stock was superseded in early historic times by the Celt or Gaul who conquered or peacefully infiltrated the region of central Europe and the British Isles, but did not drive out or exterminate the little dark men of prehistory. The Celt (Pls. II and V) was about as different from the Iberian as one white man could be from another, being a giant in size and strength, with yellow hair and blue eyes, ruddy complexion, and a large, round head not high, but with beetling brows. The intermingling of these two extreme types of the white race has resulted in the Celt-Iberian (Pls. IV and VI), who is in nearly every measurable feature intermediate between the Celt and Iberian as they originally existed, but with the coal black hair of the Iberian and the blue or gray eyes of the Celt. Hair color and eye color are evidently separate characters, as they have not blended, and may follow Mendel's laws.

When the Celt overspread Europe, and came to England and mingled with the Iberian, the Celt-Iberian, or Blend No. 1, was formed. This formation represents the hybrid. The Iberian and the Celt reappeared in succeeding generations, but in time became more and more alike, until at present the differences are slight, as is shown by the measurements of the two types. The Celt-Iberian has continued and to-day represents the hybrid of the two existing types, the Celt and the Iberian. The Northern and Iberian came together at a later period in the same manner and formed the Blend No. 2 or Northern-Iberian. The Celt and the Northern type must have mingled and some of those included under the Northern type are undoubtedly the hybrid Celtic-Northern. The Iberian is, then, approaching and becoming like two types, the Northern and the Celt, which is apparent from the physical resemblance of the three. The Saxon and the Alpine may be considered as blends of the Celt and Iberian with a preponderance of the Celt, as in the Celt-Iberian there is a preponderance of the Iberian. The Littoral (Pl. VII) and Adriatic are distinct types as much as the Northern, Celt and Iberian, and probably represent the modernized Cro-Magnon and Neanderthal man. They are modified by the three other types, all of which have some of the characteristics of these two primitive ones, some more than others, the Northern partaking largely of the Neanderthal, the Iberian, of the Cro-Magnon. There is a progressive fusion of all the types going on at the present time, with a persistence, more or less pure, in a few individuals of some features of the primitive types. The Northern, Iberian, Littoral, and Blend No. 2, have the height, head length, and tendency to a hypsistenocephalic condition resembling the type of the Cro-Magnon, Laugerie and Chancelède man of the late paleolitic or Magdalenian epoch in Europe, or of the men from the grottoes of Grimaldi; all of these ancient remains being characterized by similar features. The Littoral has preserved more definitely the original composite traits, while the others have blended them with their intrinsic characteristics. The Adriatic and the Northern have the brow ridges, the big bone and muscular development and the shape of the sagittal outline of the head of the Neanderthal-Spy type. The occurrence of a football-player of the Adriatic type so closely resembling the Neanderthal man, indicates that the Adriatic type may be the nearest living related form to this primitive precursor, the men of Krapina being intermediate between the two. An additional factor favoring this view is the low class standing of the Adriatic type, particularly of the football-player. The Neanderthal skull is dolichocephalic, but Schwalbe has demonstrated that the brain was brachycephalic. The enlargement and development of the brain gives a brachycephalic head as is seen in the Adriatic type.

There is evidence, then, of a persistence of the riverdrift man of interior Europe, represented primarily by the Neanderthal-Spy type, secondarily at a later period by the men of Krapina, and at present by the Adriatic, with some characteristics present in the Northern and possibly in other types; as well as a persistence of the Cave man of Europe and the British Isles (Boyd Dawkins, Eskimo) in the Littoral, and somewhat modified in other types. The Semitic, Iberian and Celt, with their affinities in the types, are derived from other uncertain sources.

When a single individual of any type is considered it should not be supposed that the type is pure, but on the contrary, each individual may have possibilities in the sex cells of any number of types, and the different sex cells have a different arrangement of the chromosomes so that as frequently happens, there may be several types in one family, especially if father and mother are of extremely different types, when the possibilities are greater. This may explain the appearance of Iberian, Alpine, Northern, Littoral and Blend Number 1 in one family of my acquaintance, while in another there appears Celtic, Saxon, Littoral, Alpine and Iberian, in the former the father being Iberian or Northwestern (Littoral) and the mother Northern, and in the latter the mother Iberian and the father Celtic.

Individual characters are inherited in the same manner as these types, when they are specific and separable, as in the case of the black and white hair of guinea pigs, and Mendel's law ultimately works through the law of chance in all heredity.

It is to be noticed that none of the types are pure unless it be the Celt, and even this may have obscure recessive characters. Only by individual records of families followed for at least three generations can the tendencies herein suggested be confirmed. Boas has shown that in crossing long and short heads and wide and narrow faces (among Jews and Indians) there is a tendency toward divergence in the offspring, the more unlike the parents are; and the more nearly alike the parents, the greater the tendency toward a blend of the two. Davenport and Davenport have shown that the eye color follows Mendel's laws, dark brown being dominant to brown, brown to gray, gray to blue, the later being the pure recessive.

Certain types by reason of their numbers, their derivation and their general distribution may be considered typically American. Such are the Northern, Iberian, Saxon, Celt and Blends Nos. 1, 2, and 5. The Alpine, Vistulian, Littoral, Adriatic and Blends Nos. 3 and 4 are largely of recent foreign extraction. The trend of the American type is in the direction of increasing height, blended coloring and mesocephaly.

SUMMARY.

Physical measurements of 923 boys and 116 girls are presented, with eye color, hair color, and head outlines; and various indices of the head are computed, the brain weight is calculated, and the class standing is given. From these data types are selected representing existing homogenous entities.

Ripley's three European races predominate, Deniker's European races are found somewhat modified, and in addition to these types, five blended types are designated.

A tentative scheme for type heredity is formulated to explain the relation of the types found to the types known to have existed in the past, and to indicate existing tendencies and predict future developments of types in America.

CONCLUSIONS.

Collective evidence favors the conclusion that the prehistoric types of men in Europe have persisted to the present time, and are found in America somewhat modified; other types are found representing later intrusions into Europe; a blending of these types has transformed them and created new ones; and the apparent ultimate result will be a complete fusion of all the types.

Feminine types corresponding to the masculine are nearer in form to the primitive, not having become so differentiated.

All hypotheses and conclusions are tentative, and await other work now pending for confirmation.

My thanks are due to Dr. McMurrich for his great kindness to me during the time I was engaged in making the physical measurements, especially for taking my classes, and only through his generous assistance was I enabled to complete the work.

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ILLUSTRATIONS.

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II. Celt (Kelt of Britain) type; from North Carolina (photographs by Martin).
III. Littoral type (modified); Indian Sikh from the Himalaya Mountains (photographs by Martin).
IV. Celt-Iberian type; from Wisconsin (photographs by Martin).
V. Celt and Iberian types (photographs by Martin).
VI. Celt-Iberian and Iberian types (photographs by Martin).
VII. Iberian from Madrid, Spain, and modified Littoral from the Himalaya Mounutains (northern India) (photographs by Martin).

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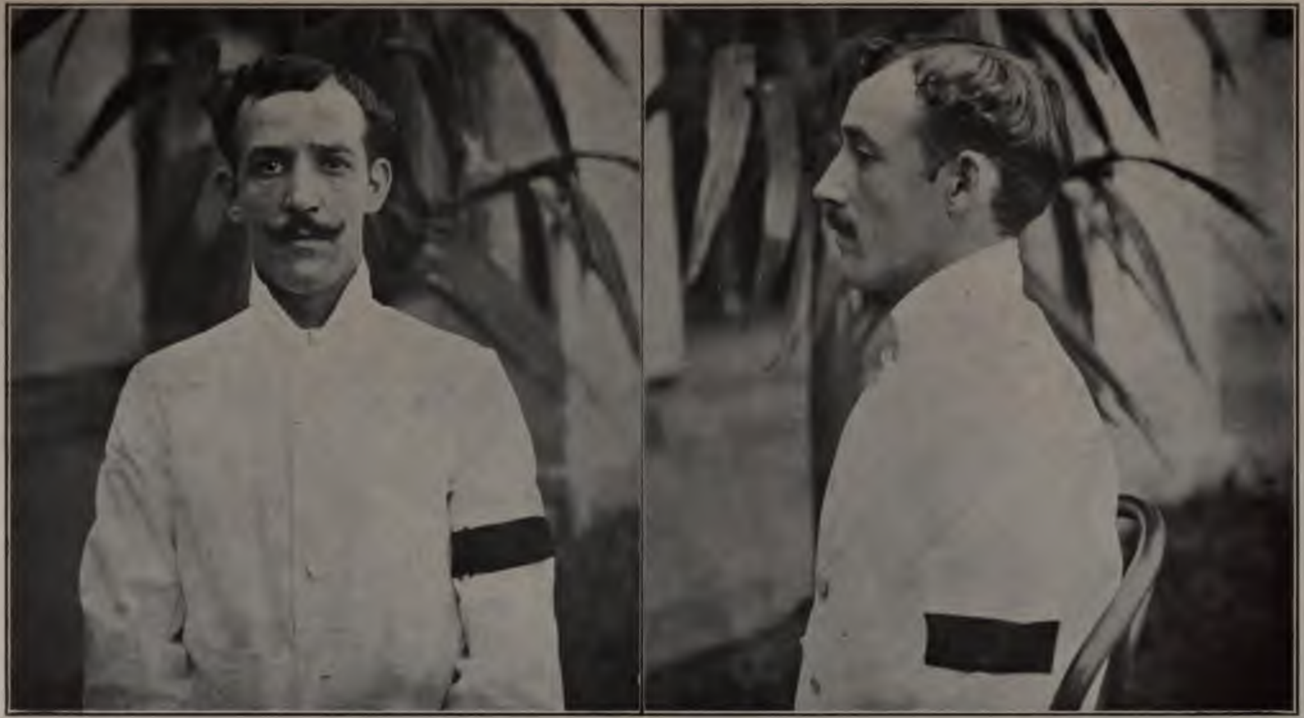

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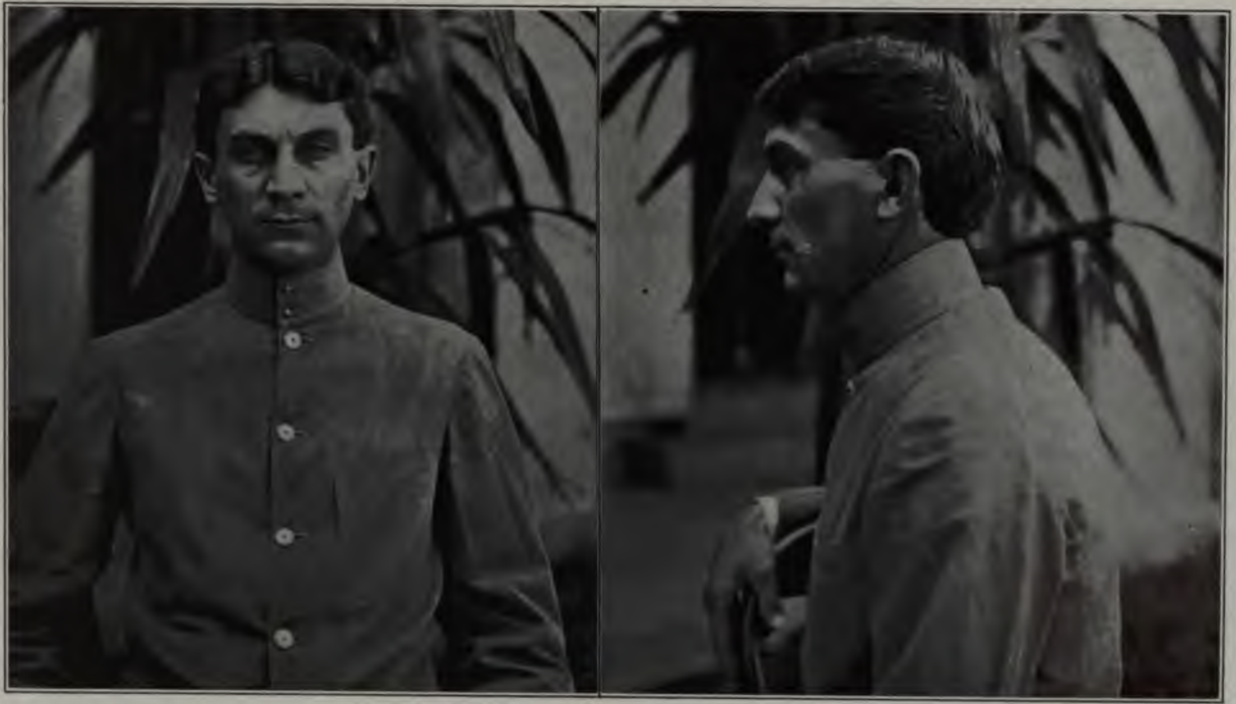

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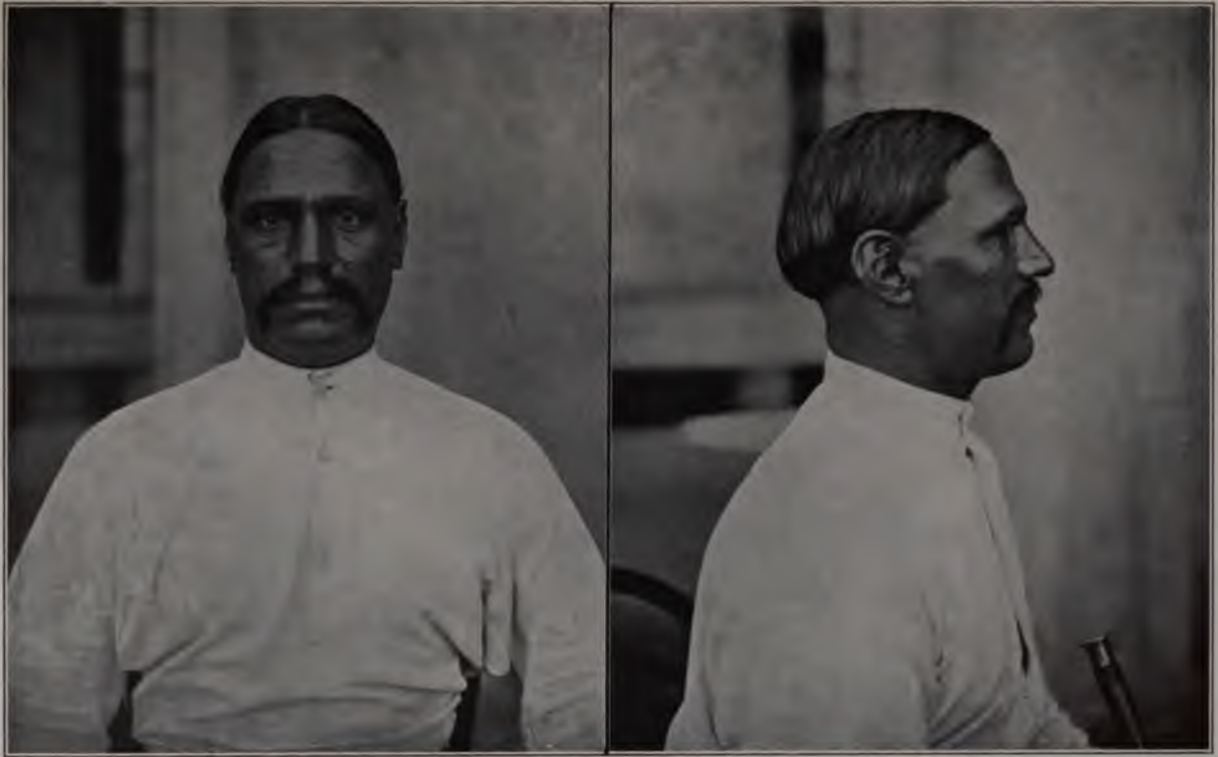

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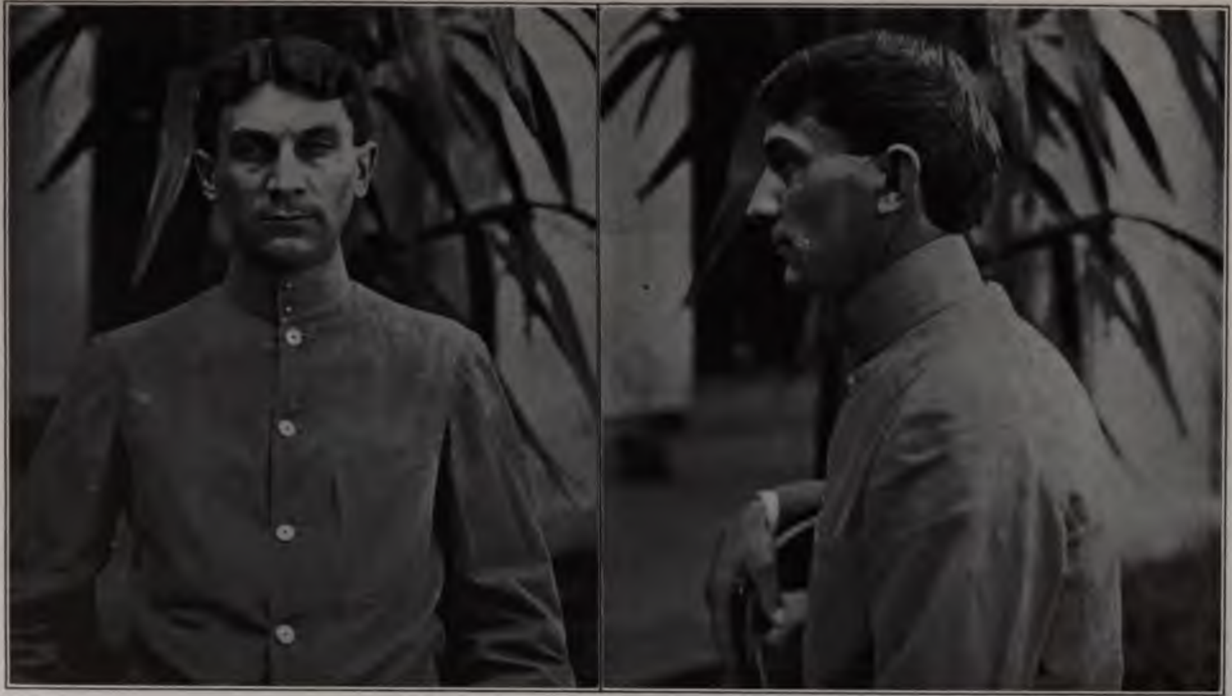
PLATE III.



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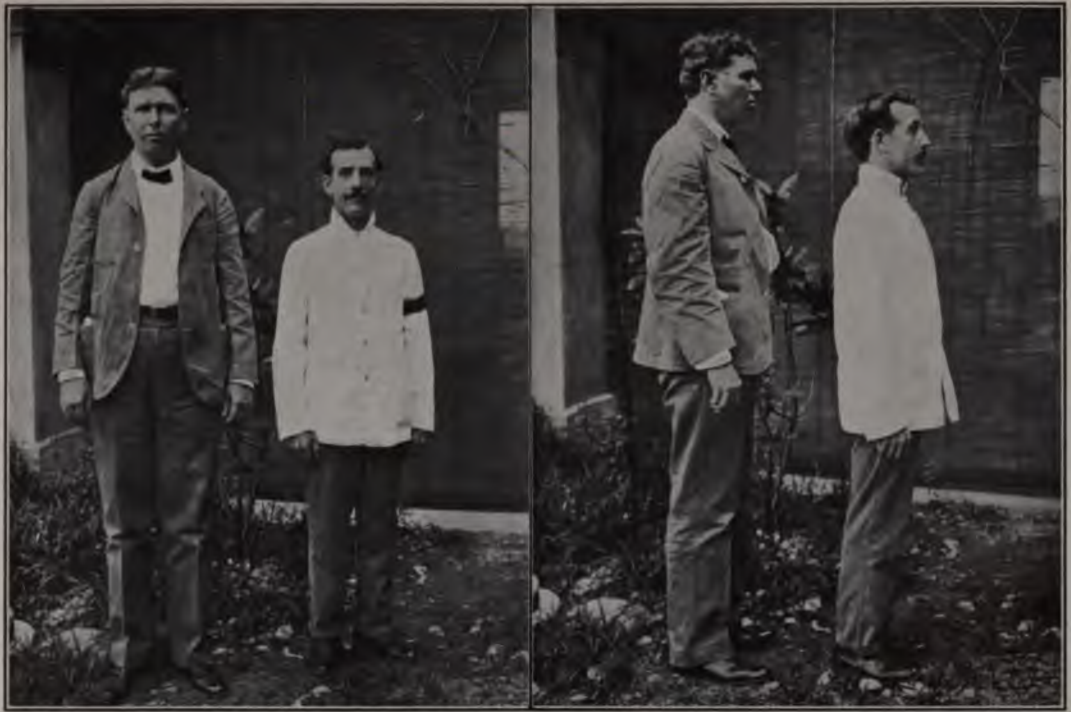

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PLATE V.

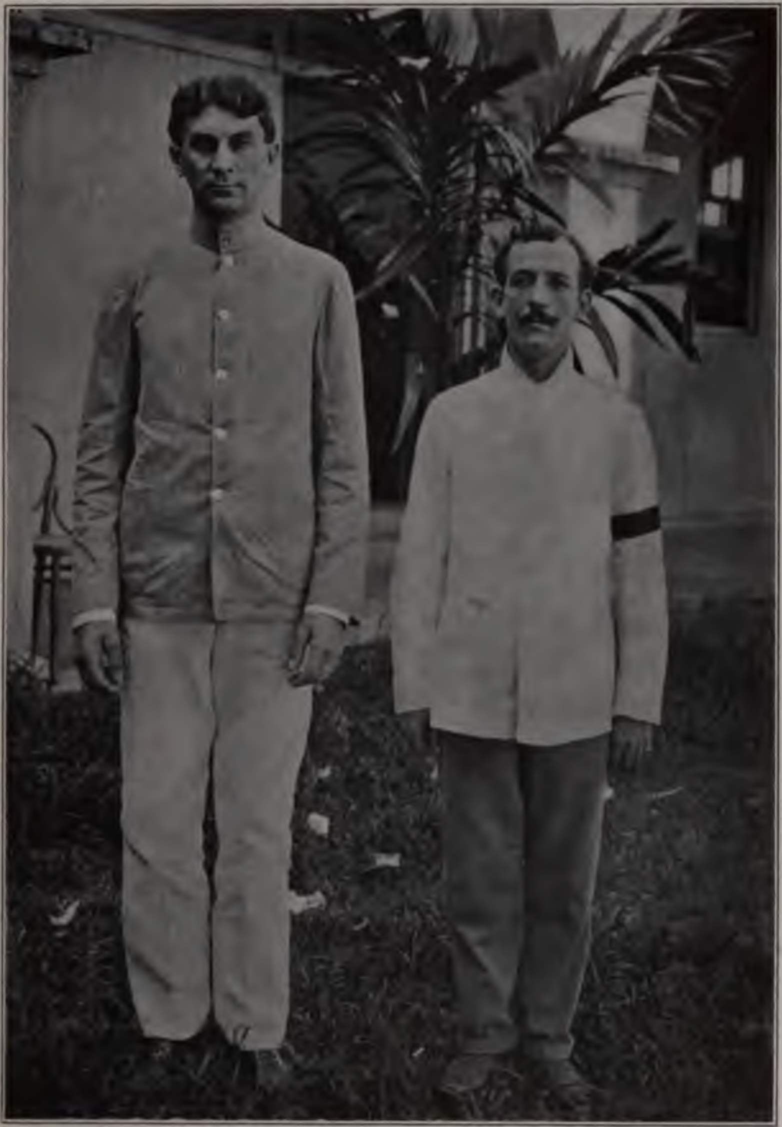

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PLATE VI.

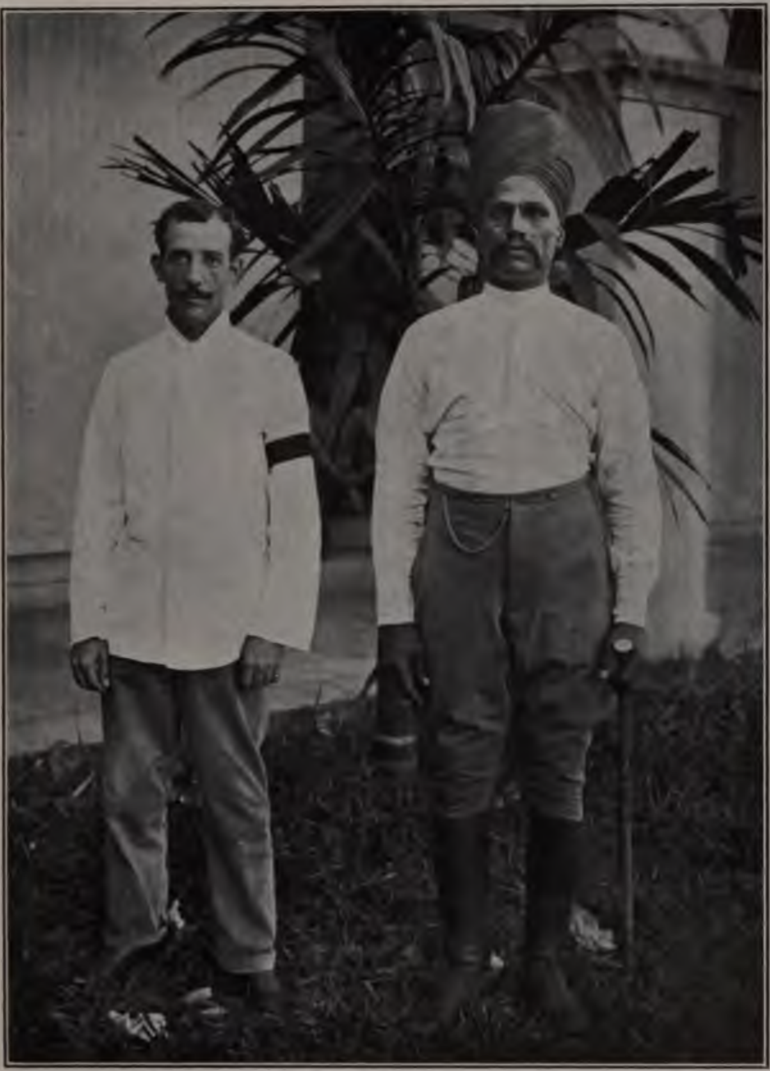

PLATE VII.

BIOLOGY OF PHILIPPINE CULICIDÆ.

By CHARLES S. BANKS.

(*From the Entomological Section of the Biological Laboratory, Bureau of Science.*)

Although nearly a hundred species of mosquitoes are now recorded from the Philippine Islands and new ones are constantly being discovered in every region where collecting is done, very little has been known heretofore of the habits and life histories of even the most abundant species, among which may be mentioned *Myzomyia ludlowii* Theob., *Stegomyia persistans* Banks, *Culex fatigans* Wied., and *Culex microannulatus* Theob.

While many species are perennial, others are abundant only at certain times of the year. Of those breeding in or near dwellings some are day flyers while others are to be encountered only after dark, being most prevalent before midnight.

There are few people who, after a year or two of residence in this region, are not able to recognize some of these pests either because of their form and coloring, or from their habits.

WORCESTERIA GRATA Banks.

Worcesteria grata Banks, *This Journal* (1906) 1, 780, 982.

Egg: The egg is 0.67 to 0.70 millimeter long and 0.43 to 0.47 millimeter in diameter, of a very broad, blunt, regular ellipsoidal shape. (Pl. I, fig. 1.) It is pure white when laid, but turns to a dirty pinkish-gray previous to the hatching of the larva. The surface appears granular when seen with a low-power lens (Pl. I, fig. 1 (*a*)), but when placed under a high power, small, sub-ovoidal tubercles are seen. Some of these appear spherical with a spinous projection. These tubercles vary greatly in size (Pl. 1, fig. 1 (*b*)), and their surfaces are coated with a filamentous, powder-like substance, impervious to water. The egg is thereby made to float perfectly upon the water, no part of it being submerged at any time. The largest tubercles measure 0.014 millimeter by 0.01 millimeter (Pl. I, fig. 1 (*c*)), while the smallest are about 1 μ.

When the larva is about to hatch, the egg shell splits irregularly around the short circumference in such a way as to leave the ends joined together by a narrow strip. (Pl. I, fig. 1(*d*).) The eggs are laid in the hollow stumps of bamboo in water which contains other mosquito larvæ. They are deposited during the late afternoon or early evening. Mosquitoes in captivity lay about 20 or 25 eggs each day during a period of two days. As many as 10 larvæ of the same size have been found in a single joint of a bamboo fence, so that it is probable that in nature the female lays more eggs than when in captivity.

Larva: The larva upon hatching measures 2 millimeters in length, and is nearly pure white; when full grown its length is 14 millimeters. The general form and appearance of the larva upon hatching is the same as it is when full grown, except in color. The distinctive appearance of the head and the lateral bristles and spines remains the same throughout the larval existence.

Full-grown larva: The full-grown larva of *Worcesteria grata* Banks measures 14 millimeters in length, exclusive of caudal bristles, and 2.5 millimeters in width, exclusive of lateral bristles. The color is carmine on the dorsal surface and pink or whitish-pink ventrally. The head is dark brown, the eyes being nearly black. (Pl. I, fig. 2.)

The surface of the body is covered at certain points by dark brown, chitinous plates or sclerites, from which the bristles and setæ grow. These sclerites are regularly and definitely arranged as shown by the figure.

The head, which is slightly more than half the length of the thorax and a little more than half its width, is subquadrate in general outline, the anterior portion being somewhat more acute than the posterior, the outer angles of which are rounded.

The eyes are situated about half way from the front under a lateral, longitudinal carina. The antennæ are less than half the length of the head, have three sub-apical bristles on the inner margin and a single apical one. A bristle projects on each side of the face near the median line. Three project laterally beneath each eye.

The arrangement of the thoracic bristles is somewhat the same as in *Myzomyia ludlowii* Theob. There are two distinct types of bristles upon the thorax. Those growing from the chitinous sclerites are setose or plumose, while those from the other portions are simple, as shown in the figure.

The setæ or hairs found upon the body segments are so arranged and of such length proportionately that when spread out laterally, which is their normal position, they make the gross outline of the larva an acute oval or lens shape.

The ninth segment and breathing siphon are of a structure meriting special note. The entire segment is covered with a brown, chitinous sclerite, the posterior, lateral and ventral edges of which are minutely serrate or dentate. A single plumose seta projects from the posterior lateral margin, and below this seta and projecting posteriad to it is a series of long, fine, simple hairs.

From the posterior portion of the dorsal margin of the segment projects a small, fleshy tubercle from which there grows a cluster of long, simple hairs, ten in number. This tubercle serves as an anchor when the larva rests against the side of the vessel in which it breeds.

The anal papillæ, which I shall term anal tracheal gills and which, undoubtedly, serve as a secondary respiratory apparatus, are very short and evenly rounded, scarcely projecting beyond the posterior margin of the ninth segment.

The respiratory siphon is short and stout, the length being only slightly more than twice the width of the base. The entire surface of the siphon, with the exception of the articulation at the base, is covered by a single chitinous sclerite. From a small, soft tubercle at the posterior edge of the base, fine, short, stout pectinate bristles project. These bristles are not as long as the diameter of the base.

Ventrad to the base of the siphon, on each side of the eighth segment, is a single, subtriangular, chitinous sclerite, from the posterior edge of which project caudad two pectinate bristles, one from the middle and one from the ventral angle. (Pl. I, fig. 3.)

The larva of *Worcesteria grata* Banks is purely carnivorous, but I have never noted an instance in which it was cannibalistic. Three larvæ, nearly full grown, were placed in a 2-liter glass jar for two days without food, and during that time none of them attacked the others, although as soon as larvæ of *Desvoidya joloensis* Ludlow were put in, they were attacked by the *Worcesteria* larvæ.

The number of larvæ of different kinds devoured by one of *Worcesteria grata* Banks during its period of growth is quite astonishing. The record for three larvæ is given herewith:

Fifty eggs laid July 12, 1906. Larvæ hatched July 16, and all died except four. About four hundred larvæ of *Culex fatigans* Wied., which hatched the same day, were fed to the *Worcesteria* larvæ on July 16, in addition to three half-grown *Culex* larvæ already in the jar.

Five half-grown larvæ of *Stegomyia persistans* Banks were fed to them on July 17, and ten full-grown larvæ of the same species during the afternoon of July 17. The first molt of the *Worcesteria* larvæ occurred during the night of July 17, and during the day of July 18 they almost doubled in size. On the 18th day of July, in the night, one larva died from an unknown cause.

Twenty-five full-grown *Stegomyia* larvæ were fed on July 18. The second molt occurred during the night of July 19. On July 20, twenty full-grown *Stegomyia* larvæ were fed. The third molt occurred at noon of July 21. Fifteen full-grown *Culex fatigans* Wied. larvæ were fed on July 22 and fifteen more on July 24. On July 24 the *Worcesteria* larvæ appeared to be about full-grown. On this date four full-grown *Stegomyia* larvæ were fed, and twenty more were given on July 25. One larva pupated on July 26 during the early morning, and another later on the same day. The remaining larvæ ate nine *Stegomyia* larvæ and pupated at 5 p. m. on July 29.

Two adults emerged during the early morning of August 1, and the remaining adult on August 3. These were all females, and were from eggs which were laid by a single female which emerged in Iloilo on July 6 in company with a number of males taken from material which I had brought from Mailum in the town of Bago, Negros Occidental.

During my stay in Negros, I was unable to obtain eggs of this species for rearing. However, the larvæ were captured in considerable numbers and the following notes as to their growth are given herewith:

May 26: A nearly full-grown larva captured. This was the first of this species and was taken in a bamboo joint associated with numbers of *Desvoidya joloensis* Ludl., but on June 7 it died.

June 7: Four nearly full-grown larvæ taken, each from a different bamboo joint. The water in these cups was perfectly clear and clean and contained larvæ of *Stegomyia samarensis* Ludl.

June 12: One larva pupated.

June 14: A second larva pupated.

June 17, 7.30 p. m.: The pupa from the larva of June 12 changed to an adult female.

June 19, 11.40 a. m.: An adult emerged from the pupa of June 14.

June 20: Eight larvæ were found in the liquid in the top of a bamboo ladder at the front door of a native's house. There were numerous other larvæ of *Culex* sp. and maggots of some other unidentified dipteron. The liquid was composed of rain water and urine voided into the receptacle by the children of the house, they having scooped out the larvæ and brought them a half mile to the house where I was working, as I had promised a reward of 1 centavo ($0.005) for each larva captured.

June 21: Ten larvæ were taken from a large bamboo fence post, and two from each of two other posts.

June 24: The larvæ began pupating.

June 28: The receptacle was transported 18 miles to the coast where I was to embark.

June 29: Adults began emerging.

July 1: All larvæ had transformed to pupæ.

July 6: The last adults emerged in Iloilo.

The total number of adults was twenty-four and of this number five were saved for breeding, including two females and three males. The remainder, some of which had been slightly damaged, were killed and pinned.

July 6: The insects copulated, the females hanging from the gauze cover of the jar and the males clinging to the ventral part of the females' bodies. These insects were fed upon bananas which they relished greatly, refusing all other kinds of food, including sirups which they seemed to shun.

July 7: One female died.

July 8: One male died.

July 10: The three remaining insects, two males and one female, were placed in a large glass jar containing a bamboo joint half full of water.

July 11: The two remaining males died.

July 12: The female began laying eggs, continuing until July 13, the total number being about fifty.

July 14: The eggs began hatching and continued to do so until July 15.

Many of the larvæ died from lack of food and only four were saved, as was stated above.

July 14: The female died and sank to the bottom of the bamboo joint where she was found on the morning of July 15.

The life of these four larvæ has been given above.

HABITS OF THE LARVÆ.

The larvæ of *W. grata* Banks remain in almost a horizontal position upon the surface of the water, only going below when pursuing their prey or when disturbed. When chasing other mosquito larvæ, they move directly forward by a snake-like wriggling which is very slow and stealthy. When they have approached within reaching distance, they make a quick forward dart and seldom fail to capture their prey. They frequently take other larvæ which have just come to the surface, by simply twisting the body and making a straight lunge for the unsuspecting victim; once they have caught a larva, they begin eating and do not pause until they have consumed the entire carcass. Sometimes they begin at the head or in the middle, but most frequently they eat from the tail and forward while the captive still moves. When at rest in a bamboo joint, they remain anchored to the sides by the caudal setæ, their heads pointing toward the center.

Larvæ, when living under conditions in which they can obtain an abundance of food, eat such large quantities that they grow very fat, and some of them, just before the period of pupation, appear as if about to burst from the accumulation of adipose material.

Pupa: The pupa is light brown. It measures 14 millimeters in length over the dorsum, and 4 millimeters across the thorax.

Two small, submedian bristles project cephalad from each side of the dorsal metathoracic segment. Posterior to these, on each side of the dorsum of the first abdominal segment projects a tuft of fine plumose bristles.

Each of the remaining abdominal segments, except the seventh and eighth, bears on its posterior dorso-lateral margin a long bristle or in some instances two. The seventh segment bears a spine-like bristle and four others, all growing from the same point.

The pinnuræ are large, nearly circular, and with a fine fringe along the outer margin from the vein to near the base. They are devoid of urochaetæ.

The respiratory siphons are large, but not disproportionate. Their bases are only slightly smaller than the apices, which latter have a sub-oval respiratory opening. (Pl. I, fig. 4.)

The pupa usually remains quietly at the surface, but upon the slightest provocation swims rapidly to the bottom, except when about to transform. This operation generally takes place in the late afternoon.

HABITS OF THE ADULT.[1]

Several notes have been published with regard to the habits of this group of mosquitoes. All agree that the members are sylvan in habitat, but observers differ as to their being harmless to man and animals.

Theobald says:[2]

> "It is erroneously supposed that they are not annoying to man and animals; several occasion severe irritation from their bites. Captain James, I. M. S., sends me the description of one (*Megarhinus immisericors* Wlk.) which is very troublesome in India." He says further, in speaking of *M. separatus* Arrib.: "They are called 'carapana' in Brazil and bite very badly in the daytime and at night."[3]

Having had the good fortune to be able to rear large numbers of this interesting mosquito, and having read that the members of this group are considered to be voracious bloodsuckers, I determined to experiment in order to discover whether this species has such propensities. Two things prompted me to the conclusion that it does not suck blood—first, it is a purely sylvan species; and second, the gross appearance and manner of manipulating the proboscis would seem to point toward non-bloodsucking habits.

All the mosquitoes, both males and females were given an opportunity to bite, being placed upon my bare arm, and upon those of Filipinos and others; but aside from walking over the surface and touching it occasionally with the palpi and tip of the proboscis, they made no attempt which could be interpreted as aggressive.

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[1] For description of the adult see *This Journal* (1906), 1, 779.

[2] *Mono. Culic.* (1901), 1, 217.

[3] *Idem* (1903), 3, 114.

They fed freely upon soft banana and pineapple and a female was observed drinking water from the vessel in which she was confined, but they would not sip either plain or fruit syrups.

As these experiments were tried at all hours of the day and in the evening, they would seem to be fairly conclusive proof of the innocence of this mosquito in regard to a habit of sucking blood.

I have dissected the probosces of both male and female specimens and while each shows a development of the labrum-epipharynx which might suit it for piercing, the apices of the mandibles and maxillæ are not serrated, but are soft and thin and in no way adapted to piercing; while the dorsal suture of the tube-like labium is so constructed as practically to prohibit its separation, as in the case with biting mosquitoes when the piercing organs have been inserted into the skin of the victim. In other words, the labium is better adapted to sucking juices which lie upon the surface, while the sharpening of the labrum-epipharynx is merely a morphological relic.

The few specimens of this species which have been captured as adults were invariably taken during the late afternoon, so that *W. grata* Banks could not in all probability be classified as a day mosquito.

As the larvæ of this species destroy enormous numbers of those of other mosquitoes, experiments looking toward their propagation would be valuable. Their introduction into tanks and other receptacles where mosquitoes breed, especially in gardens and dense coppices, might tend to their greater abundance near dwellings; and even if they were to attempt to attack man, their great size would render them sufficiently conspicuous as to allow of their being easily driven off. However, I am thoroughly convinced that the latter contingency would never arise. (See Pls. II and III for male and female adults.)

DESVOIDYA JOLOENSIS Ludlow.

Desvoidea fusca joloensis Ludlow, *Can. Ent.* (1904), **36**, **236**.
Desvoidya ———— Banks, *This Journal* (1906), **1**, **983**.
———— joloensis Theob., *Mono. Culic.* (1907), **4**, **163**, **165**.

This mosquito was found to be abundant during the months of April, May and June, in upland villages surrounded by woods and bamboo thickets. It has also been taken in Manila.

Egg: The egg of this species is quite similar in general appearance to that of *Stegomyia persistans* Banks, except that it is about one-ninth to one-eighth longer and the sides are more nearly parallel. The ends are more obtusely rounded. The sculpture of the air cells is nearly the same, except that the hexagonal figures are not elongated transversely. It is 0.84 millimeter in length. (Pl. IV, fig. 1.)

OVIPOSITION.

A female of *Desvoidya joloensis* Ludl. was observed flying around the open bamboo cups of water upon the table in my temporary laboratory at Mailum. The female entered one of these and was seen to crawl down the side of the vessel backwards. When near the surface of the water, *i. e.*, on the moist zone of the cup, she curved the abdomen downward and immediately deposited a cream-white egg. This operation was continued until four or five eggs had been laid. She then flew to the opposite side of the cup, crawling around and palpating the moist surface with the tip of the abdomen until another spot to her liking was found, whereupon she deposited several more eggs. A piece of gauze was placed over the cup and the mosquito continued her egg laying. The next day, as she had apparently laid all her eggs, she was killed and pinned.

The eggs hatched two days later.

Larva: The full-grown larva is 10 to 12 millimeters long. (Pl. IV, fig. 2.) It is either pure white, or as is more common, of a pinkish hue, especially over the dorsal areas of the abdominal segments and the thorax. Occasionally, a very dark specimen will have fainter indications of the same color on the ventrum.

The head is very broadly oval, nearly circular in outline. The frontal area has four transverse simple setæ, the two nearest the median line being two-thirds the length of the outer ones. A bifid seta projects laterad from below each eye-spot and another of the same kind, four times as long, projects caudad from the posterior inner angle of the eye-spot itself. The terminal (second) segment of the antennæ is very minute, being less than one-fourth the diameter of the first.

The posterior pseudopoda are the best defined, being very large and projecting from the posterior lateral angle of the thorax. The mid and anterior tubercles are well defined, but not prolonged into pseudopoda.

Each tubercle bears finely pectinate setæ.

The abdominal segments bear single, simple setæ on their lateral margins, and on the posterior dorso-lateral area, a single bifid seta. In addition to these there are on the first, second, third, fifth, sixth, and seventh very minute, lateral bifid setæ, hardly perceptible. Otherwise the larva is quite bare of setæ.

The respiratory siphon, which is chitinous for three-fourths its length from the tip and devoid of pecten scales, is twice the length of the eighth segment, from the longitudinal axis of which its axis is deflected only slightly.

The ninth segment is very short and bears a dorsal setiferous, chitinous sclerite, subtriangular in general outline, and with crenulate margins. The dorsal anchor bristles are short and pectinate, about ten in number; the ventral twice as long and of similar structure, being composed of eighteen setæ.

The anal tracheal gills are very robust, ellipsoidal, white, mottled regularly with gray annulations and are one-half longer than the respiratory siphon.

The lateral comb is composed of eight blunt, irregularly placed scales. (Pl. IV, fig. 3.)

The length of the larval stage is about five days.

HABITS OF THE LARVÆ.

These are the most sluggish culicid larvæ that I have ever seen. They move slowly and with a forward, wriggling motion, remaining for long periods beneath the surface, and usually feeding among the chips of bamboo to be found in the cups after the tree has been cut down; or in the case of fence posts, where the top has been trimmed. They fall an easy prey to the larvæ of *Worcesteria grata* Banks, which are nearly always found where the *Desvoidya* larvæ breed.

The very large size of the anal tracheal gills provides for subaquatic respiration, and the insect finds its food in the bottom of its breeding receptacle, so that it need not come frequently to the surface. As the *Worcesteria* larva seldom goes below the surface region, it must catch the *Desvoidya* larva when it rises, and this act it performs very skilfully, quickly darting its head around in an arc of a circle, using its respiratory siphon as a pivot or center. The *Desvoidya* larva once captured, makes very few struggles, as if realizing that it is helpless against its stronger foe.

The larvæ of this species are always very fat in the latter period of their growth, and from this fact I strongly suspect them to be cannibalistic, the larger preying upon the smaller, although I have never had ocular demonstration of this. One seldom or never finds larvæ of assorted sizes in the same receptacle and this would be somewhat of a proof that the smaller are not allowed to live with their larger fellows.

It might be suggested that the equality of size in these larvæ could be explained by the fact that all the eggs are laid at a given time, but the adults have been seen depositing their eggs on different days in the same cup.

Pupa: Length over the dorsum, 8 millimeters; of a rather light brown until a day or so before the adult emerges, when it turns black and white, the adult colors showing through the pupal skin.

Both the first and second abdominal segments bear a pair of dorsal plumose setæ, those on the first being very much larger than the other pair.

The respiratory siphons are cornucopia-shaped, the anterior portion of the lip being truncate.

The pinnuræ are irregularly oval, being broadest at the distal extremity, and retuse at the point where the vein meets the margin. The cilia are quite long and extend around the entire distal portion from the middle of each lateral margin. The surface is finely reticulate and slightly pilose.

The urochaetæ are one-fifth the length of the pinnuræ and are straight except at their bases, where they are sharply curved. (Pl. IV, fig. 4.)

The seventh abdominal segment bears at its posterior lateral angle a 4-parted pectinate spine, while the eighth has a similar longer one of ten branches.

The pupæ are very lethargic in their movements, remaining grouped together at one side of the containing vessel. The pupal stage lasts for three to four days.

Adult: The adult specimens reared by me conform in every respect to the description given by Ludlow.[4]

These insects fly in a very leisurely manner and with the hind legs curved upward over the back, the fore and mid legs spread out considerably from the body on each side and the tarsi recurved. The note made by their wings is very low, due to the slow vibration.

In the early morning, about daybreak, and in the early evening, they are always abundant in regions near forests. They are vicious biters and inflict a very painful sting, which lasts several hours. They occasionally enter houses.

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[4] *Can. Ent.* (1904), 36, 236.

STEGOMYIA PERSISTANS Banks.

Stegomyia fasciata persistans Banks, *Philip. Journ. Sci.* (1906), 1, 984, 996.

Egg: The egg of this species measures 0.75 millimeter in length. It is a long, slender oval, slightly blunt at one extremity. It is a light gray when laid, but within a very short time turns jet-black. The surface is very finely reticulated.

The eggs are laid singly at the water line upon the sides of vessels in and around houses, most frequently in receptacles containing rain water.

The period of incubation is twenty-four to forty-eight hours according to the temperature.

Larva: The larva upon emerging measures 1.2 millimeters and is light gray, with the exception of the head which is brown-gray.

The larval period lasts seven to ten days, during which the greatest growth is made in the first five days.

The full-grown larva measures 10 millimeters in length and is most readily distinguished by the color of the respiratory siphon, which is dark chestnut-brown.

The body segments, including those of the thorax, are very pale and semitransparent. They are sparsely clad with setæ, the three lateral groups on each side of the thorax consisting of from eight to sixteen setæ each. The pseudopoda on the latero-ventral area are well defined, the ungues of the middle and posterior pair being prehensile, while the anterior pair have none. Small chitinous sclerites mark the position of the mid and posterior dorso-lateral pairs of setæ.

Quadrifid bristles grow from the dorso-lateral area of the first three abdominal segments and dorsal to these are very short trifid setæ.

The remaining abdominal segments have long, lateral, trifid or simple bristles and simple to quadrifid setæ of very small size on their posterior areas.

The lateral comb of the eighth segment consists of ten comb scales, dorsad, ventrad, and caudad of which on each side is a quadrifid seta. The pecten scales are fourteen in number with a quadrifid bristle on the air tube at their apical limit.

The lateral comb of the eighth segment consists of ten scales, dorsad and ventrad to which on each side is a quadrifid seta; posterior to the middle of the comb on the margin of the segment is a long quinquiefid, pectinate bristle.

The general appearance of the ninth segment is like that of *Worcesteria grata* Banks, the chitinous sclerite covering nearly the whole segment. From the posterior dorsal margin grow the dorsal anchor bristles to the number of six. These are twice the length of the anal tracheal gills ("anal fins" of Theobald) which, in turn are twice as long as the ninth segment.

The larvæ of this species may be distinguished from those of *Stegomyia samarensis* Ludl., by the latter having the surface of the anal tracheal gills covered with minute, regularly placed annular spots. In *S. persistans* Banks, the tracheæ in these gills are 4- or 5-branched.

Ventrad to the tracheal gills, on the posterior margin of the ninth segment, are the twelve ventral anchor bristles of the same length as the dorsal, but less curved than they.

The respiratory siphon is slightly less than twice as long as the diameter of its base. It is naked except for the pecten scales, a quadrifid bristle before mentioned, and six minute setæ at the apical extremity around the tracheal opening. The surface is finely, transversely reticulate or striate.

HABITS OF THE LARVÆ.

The larvæ may be found in all kinds of receptacles where water collects in and around houses. They much prefer rain water and might almost be called an exclusively rainy-season species, being very much more abundant at that time than during the months from December to May.

The full-grown larvæ feed almost exclusively at the bottom, coming to the surface occasionally to breathe and always to molt. In the latter case, unless disturbed, they remain motionless for several hours previous to shedding their skins.

Whenever an object comes near, or the vessel is jarred, all larvæ go to the bottom where they may remain for several minutes. This feature has a great bearing upon their propagation. As the water in most vessels where they breed is dipped from above, instead of being drawn off from a tap at the bottom, the mosquito larvæ are seldom dipped up because they dive quickly when the surface is disturbed. Even in a pitcher in daily use and in which the water is renewed when low, they may successfully complete their life period. Several cases of this kind have come to my notice, the persons interested asserting that the water in the pitcher or other vessel had been renewed daily, but never taking notice of the fact that the small quantity which always was allowed to remain in the pitcher contained the larvæ.

These larvæ have never been observed feeding upon one another nor upon the larvæ of *Culex fatigans* Wied., with which they are often associated. They feed largely upon the sediment contained in the dregs, which may be both animal and vegetable in its character, but more frequently vegetable, as it is composed of the bits of decaying *nipa* forming the roofs from which the rain water is collected.

The larvæ, in feeding, move forward over the bottom of the vessel, taking in the particles of food with great rapidity and rejecting tiny morsels of undesirable material in a constant stream.

The larval period lasts from five to eight days.

Pupa: The pupa measures 6.5 millimeters over the dorsum. It is gray when newly transformed, but soon turns to an almost black-brown, the markings of the adult showing plainly after the second day. The pinnuræ are thickly clothed with fine hairs, their entire margins being likewise so adorned. The urochaetæ are perfectly straight and are one-fourth the length of the pinnuræ. A single, very large, simple bristle projects from the postero-lateral angle of the eighth segment, while a few others are found on the posterior dorsal and ventral areas of the remaining abdominal segments.

The first abdominal segment is ornamented dorsally by a peculiar, compound, submedian bristle. This bristle, simple and stout at its point of origin, divides into eight or nine branches, each of which in turn divides into as many more, the last being pectinate, so that the appearance under the microscope is that of a regularly branching tree. Anterior to each of these peculiar bristles, are two other simple ones.

The respiratory siphons have no especial mark for characterization. Their bases are dark brown, their apices pale ochraceous.

The pupal stage lasts for three to four days.

The adult male and female are shown on Plates V and VI, respectively.

Adult: The adult insect has already been described.[5]

HABITS OF THE ADULT.

It would be difficult to imagine a mosquito, or any other insect, which could be more of a strategist than this one. It is altogether a day flier, individuals being seen after dark only on the very rarest occasions. They are extremely fond of dark objects as a place of rest and when found upon light-colored ones they are always on the shadow side.

Persons wearing black stockings are sure to be annoyed very greatly if they sit quietly in one place for any length of time. These mosquitoes bite upon the back of the hands and fingers when the individual's back is turned to the window and a book is held in position for reading. The insects are so wary that they are killed only with the greatest difficulty. After gorging themselves with blood, they fly, rather sluggishly, but directly, to a dark corner, where they will sit upon the wall or other object during the remainder of the day or night.

The bite of this mosquito is always irritating, whether it is left to finish its meal and quietly withdraw its proboscis, or whether it is killed or frightened away before it has finished. A vigorous rubbing of the affected spot will quickly cause a diffusion of the injected irritant and a rapid cessation of the itching, as I have proved by observations upon myself; but for several days afterwards, if the spot is accidentally scratched or lightly contused, the actual point of insertion of the proboscis will again begin to itch. Usually, a tiny, red, subcutaneous point is all that is visible, but occasionally there is slight œdema. The bites of this mosquito cause the most irritation when they occur upon the knuckles of the fingers, a favorite place of attack.

A female of this species will continue her attacks for an hour if she is continually driven off, the insect generally flying up and behind the victim and returning at the side and under the arm of the chair in which he may be sitting. Only a few minutes at rest are necessary before these sly pests take the opportunity of biting, and the killing of one appears to bring others, or at least they continue to come, one by one, for half an hour or longer.

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[5] *This Journal,* (1906), 1, 996.

This mosquito does not bite immediately when it alights upon the hand; rather, she stands as if waiting to see if she will be molested, and, if not, she probes for a moment with the tip of the proboscis and then at once inserts it.

The males have the peculiar habit of flying back and forth in front of anything upon which they are about to alight. This they continue for some time, remaining at a distance of not more than five centimeters from the object.

Copulation: The members of this species copulate in the afternoon between the hours of five and six. A male dancing along in the air in front of an object upon which a female is resting, will, after a few passes, fly against her. She at once takes wing, and the male, pursuing and flying beneath her, clasps her with his fore and mid feet. The two insects fly in this way for about five seconds, performing the act of coition and immediately separating. I have killed many couples by crushing them between the palms of the hand and have invariably found them with the ventral surfaces toward each other. Specimens confined in small jars have been seen to copulate while the female hangs from the gauze covering the vessel, the male always approaching her from the ventral surface.

A single male will copulate with from seven to eight females if confined in a jar with them. After copulation, the males, as well as the females, rest upon a vertical surface upon their fore and mid legs, keeping their hind legs in a constant motion above the back. One leg is usually elevated much above the other.

The females have never been found feeding on anything other than blood. The males are occasionally attracted to sweets, but have never been seen to bite.

STEGOMYIA SAMARENSIS Ludlow.

This species is both sylvan and domestic and while not by any means as abundant in dwellings as *S. persistans* Banks, it is a veritable pest in the forest during the entire day, but more particularly in the late afternoon.

It may be distinguished at once from *S. persistans* Banks by the white, median, dorsal stripe on the thorax. It is, as a rule, a slightly larger species and is not so active as *S. persistans*.

Egg: Length 0.75 millimeter. The egg of this species is practically identical in shape and size with that of *S. persistans*, the only difference being that it is slightly broader across the blunt end. The eggs are laid in the woods, in hollow bamboo joints and are placed upon the soft, wet substance of the joint just above the water. The length of the incubation period is one and one-half to two days.

OVIPOSITION.

A female of *S. samarensis* Ludl. was observed at 11.30 in the morning walking around inside a bamboo cup half full of water and hung in a betel-nut grove. Upon closer observation she was seen to be in the act of egg-laying, the process being as follows: The abdomen is depressed or recurved until the tip comes in contact with the surface of the vessel, the insect walking around in this position until the abdominal cerci touch the moist surface. She stops and immediately deposits a single egg in the slime just above the water. This operation is repeated at intervals of about half a minute, but she may stop for two or three minutes after having laid ten or twelve eggs. In this case she rests, head up, upon the fore and mid legs, the hind legs being kept in motion. The female, during egg-laying, always assumes a position in which the head is farther from the water than the posterior extremity of the body.

The eggs are pure white when laid, but in less than an hour change to a dark, bronzy-brown. The surface is covered with irregular, elongated hexagonal air cells. (Pl. VII, fig. 1.) The eggs are evidently cemented to the slime, because it is not possible to remove them without the adhesion of a small piece of the slime or plant fiber.

Larva: Length 9 to 10 millimeters. (Pl. VII, fig. 2.) The larvæ of *S. samarensis* Ludl. differ when full grown from those of *S. persistans* Banks in being clothed with a greater number of quadrifid setæ upon the abdominal segments, and by the presence upon the surface of the anal tracheal gills of a regularly arranged series of very minute, annular spots. This is found in the full grown larvæ of the species and is the surest means of differentiation.

The pecten scales are twelve to fourteen on each side, while those of the lateral comb of the eighth segment vary in the same specimen, there being eight on one side and ten on the other in several specimens examined. The lesser number has been found always on the right side. (Pl. VII, fig. 3.)

The time required from the egg to the pupa is five to seven days, although larvæ kept without food have lived 15 days.

Pupa: The pupa of this species differs from that of the preceding in the following particulars: The secondary branches of the compound setæ of the first abdominal segment are much longer, the pinnuræ have longer fringes and their surfaces are not covered with pubescence; they are also longer and narrower and their apices are subacute while those of *S. persistans* Banks are rounded. The respiratory siphon is rather slender, its apex being nearly circular.

The pupal stage lasts two to three days. The pupæ behave very much as those of the other species except that they swim with a longer stroke of the abdomen, thereby making fewer strokes to the minute.

Adult: This species has been described by Ludlow.[a]

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[a] *Journ. N. Y. Ent. Soc.* (Sept., 1903), **11**; *Can. Ent.* (1904), **36**, 71; *Idem* (1905), **37**, 134.

Very great variety exists in this species, individuals emerging from the same batch of eggs showing marked instability of pattern. I do not propose to indicate or even suggest that they should be considered other than mere aberrations due to conditions of growth, but they at least demonstrate that there is a decided instability in this species or subspecies, whichever it may eventually prove to be. I indicate them with letters merely for convenience:

Var. a.—In this specimen there is on each side of the mesonotum at its base, a very thin, white line extending cephalad one-fourth the length of the segment, then curving outward exactly as the lyre pattern in *S. persistans* and *S. fasciata.* This curved line is very faint. Laterad to this line is a broad, straight, silvery, interrupted band from the prothoracic lobe to the base of the wing. Two specimens, both females.

Var. b.—The joints of the antennæ in this specimen, which is a male, are pure white on their margins. The median mesothoracic band is very faint.

Var. c.—This fine specimen has the lateral band of *var. a* extending dorsad to the base of the wing and terminating at the scutellum. The band is heavier and the scales are more distinct and quite silvery. The interruption is very slight, so that except under a lens the band appears as if continuous. It is confluent with the white, postocular cephalic band. Below this band on the anterior area of the mesoplura is another white band parallel with it, but terminating cephalad at the prothoracic lobe. The indications of the lyre-mark, although present, are very faint. It is a female.

Var. d.—This specimen has an abnormally broad median, white, longitudinal cephalic band. It is a male.

Var. e.—In this variety, the posterior tarsi are black, except for a very faint, white patch at the bases of the first and second segments. The lateral lobes of the scutellum are also black instead of silvery as in the typical specimen and in all the other varieties enumerated.

HABITS OF THE ADULT.

The adults of this species in the forest behave somewhat as those of *S. persistans* in houses, although they are not quite so persistent in their attacks. Their bite is equally as painful as that of the other species. Their average size is also greater and the note made by the vibration of the wings consequently has a lower pitch. It is easily possible to distinguish four distinct tones with males and females of both species together in a jar, those of the male of *S. persistans* being highest, those of the male of *S. samarensis* next, followed by those of the females respectively of *S. persistans* and *S. samarensis.*

In Manila, the adults of this mosquito are occasionally found in houses and their larvæ may be seen associated with those of *S. persistans* in the cups formed by bamboo fence posts. There is no means of distinguishing between the larvæ by a casual examination, and, economically, there is really no need to do so as they should both be placed in the "pernicious" class.

In dwellings, these mosquitoes fly during the same hours of the day as do *S. persistans*, but are to be encountered much less frequently.

HULECOETOMYIA PSEUDOTAENIATA Giles.

Stegomyia pseudotaeniata Giles, *Journn. Bombay Nat. Hist. Soc.*, **13**, 607.
——————, *The Entomologist* (1901), **36**, 192.
—————— Theobald, *Mono. Culic.* (1901), **1**, 312.
—————— Giles, Handb. of Gnats (1902), 379.
Hulecoetomyia pseudotaeniata Theob., *Gen. Ins., Culic.* (1905), 20.
—————— Banks, Philip. Journ. Sci. (1906), **1**, 986.
Hulecoeteomyia[7] pseudotaeniata Theob., *Mono. Culic.* (1907), **4**, 219.

This species, which lives in pot-holes in the rocks along the banks of rivers, may properly be considered a dry-season form owing to the fact that only during the dry season could it breed in abundance in such situations, as the water is then low and the rocks are fully exposed.

Very little is known at present with respect to the life history of this insect.

Egg: The egg has not been found.

Larva: The full-grown larva measures 7.5 to 8 millimeters. It is a very dark gray, almost black, the epidermis being somewhat iridescent.

The lateral thoracic setae are pectinate, and from three to five grow from each tubercle.

The pseudopoda are slightly less developed than in *Stegomyia samarensis* Ludlow and *S. persistans* Banks, which this species resembles very closely, both as larva and as adult.

The chief distinctive characteristic of this larva is the presence upon the frontal dorsal area of the head of 4 palmate bristles, each being 9–11-parted. Dorsad to the base of the antennæ on each side of the head is a 6-parted bristle. The abdominal bristles are arranged much as in *S. samarensis* Ludl.

The lateral comb of the eighth segment is remarkable in that its structure is entirely unlike *Stegomyia* and closely resembles that of *Culex lazarensis* Felt, described and figured by him from the State of New York.[8] Not only does the comb resemble that of *C. lazarensis* Felt, but the pecten scales are almost identical in shape and their number is only 5 less than that indicated in Felt's drawing.[9] Moreover, the siphon is provided with a 6-parted group of pectinate bristles at the distal extremity of each row of pecten scales as indicated in Felt's drawing.

The chitinous sclerite of the ninth segment has two rows of stout, dark spines on its posterior border; subdorsally and ventrad to these is a single, long bristle on each side.

The anal tracheal gills are three times the length of the ninth segment and, unlike any others that I have examined, are sharply conical, their surfaces being dotted with minute annular spots as in *Stegomyia samarensis*. The dorsal anchor bristles are six, the ventral from fourteen to sixteen.

HABITS OF THE LARVÆ.

The larvæ subsist upon decaying vegetable matter found in the pot-holes of the rocks in which they breed. They are very shy, hiding for a considerable time under leaves when disturbed.

[7] *Sic.*
[8] *N. Y. State Mus. Bull.* (1904), **79**, 310–311, fig. 48.
[9] *Idem* (1904), **79**, 311, figs. 50 and 51.

The larval period probably lasts for ten or twelve days, as a larva in the penultimate stage did not pupate for five days after capture and those in the last stage required three days before pupation.

Pupa: The pupa of this species resembles those of *Stegomyia* very closely with the following points of difference: the pinnuræ are circular in outline. The seventh abdominal segment has at its postero-lateral margin a 5-parted bristle while the eighth has one of nine parts.

The urochaetæ are straight and as long as the pinnuræ. The pupal stage lasts about three days.

Adult: The Philippine specimen corresponds in every respect with the description and drawing[10] by Giles, including the basal white patch on the costa.

HABITS OF THE ADULT.

Giles states that this mosquito is found in the lower Himalayas, Naini Tal and Bakloh, at 7,000 feet. In the Philippines, the altitude at which they occur is scarcely more than 35 meters. Giles further says. "I found them in a small collection of clean rain water, with some green *confervæ* in the cemented gutter round a house." [11]

I do not know whether these insects are addicted to sucking blood as I was not attacked by them during a week's stay in the region where they breed. All the specimens I obtained are from bred material.

Theobald[12] remarks that Giles' diagnosis with respect to the banding of the tarsi will not hold good for Australian specimens of the same species. This is likewise the case with Philippine specimens, the white bands involving both the bases and the apices of the joints.

This species has been found thus far in only a single locality in the Philippines, namely, at the Montalban gorge in the Mariquina River where the dam for the new Manila waterworks is being constructed.

THE FILARIA MOSQUITO.

CULEX FATIGANS Wiedemann.

Culex fatigans Wiedemann, *Aussereurop. zweifl. Ins.* (1828), 10.
—— aestuans Wied., *Ibid.* (1828).
—— pungens Wied., *Ibid.* (1828).
—— pallipes Meigen, *Syst. Beschr., Supp.* (1838).
—— anxifer Coquerel (Bigot), *Ann. Soc. Ent. Fr.* (1859), 117.
Heteronycha dolosa arribalzaga, *Dipt. Argent.* (1896), 56.
Culex macleayi Skuse, *Proc. Linn. Soc. N. S. Wales* (1896), 1745.
—— fatigans Theobald, *Mono. Culic.* (1901), 1, 151.
—— —— Giles, Handb. of Gnats (1902), 438.
—— —— Theobald, *Mono. Culic.* (1903), 3, 225.
—— —— ——, *Gen. Ins., Culic.* (1905), 28.
—— —— Banks, *Philip. Journ. Sci.* (1906), 1, 986.

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[10] A Handbook of the Gnats or Mosquitoes. London. (1902), 379, plate 14, figs. 8 and 9.

[11] A Handbook of the Gnats or Mosquitoes. London. (1902), 379.

[12] *Mono. Culic.* (1901), 1, 314.

This mosquito is by far the commonest species to be encountered in coast towns in the Philippines. It is a night flier, never attacking before 5 o'clock in the afternoon and seldom biting after 12 midnight.

Egg: The eggs of *Culex fatigans* are laid in concave rafts which float upon the surface of the water. (Pl. VII, fig. 1.) These rafts are usually about three times as long as they are broad and contain from 180 to 350 eggs, usually in six to eight rows varying in length, as will be seen on Plate IX. These diagrams represent the shapes of 18 egg-masses laid in a jar of rain water in the Entomological Laboratory during the night of September 18, 1907.

Length, 0.70 millimeters; of a dark gray, somewhat iridescent. The egg has a detachable, cup-shaped operculum at the base (Pl. VIII, fig. 2), which opens back when the larva emerges, but which is frequently not entirely detached from the remainder of the egg-shell. In the center of the operculum is a tiny protuberance or spine which, in each egg, passes downward through a small hole in the center of a very small circular fringe. This fringe is composed of radiating, elastic filaments which, when the egg touches the water, spread out in the form of an inverted saucer and support the egg in an upright position (Pl. VIII, fig. 2). It has been found by experiment that a single egg, if carefully placed upon the surface film with the tips of the fringe touching the water, will retain its vertical position. As the eggs are deposited they touch each other along their sides, and, owing to the upper end being less than the lower in diameter, the final result is a concave raft of eggs, each standing upright and being slightly glued to its neighbor. When the egg leaves the ovipositor of the female, which it does large end first, the extremities of the fringed cap are drawn together so that the cap has the appearance of a tiny sphere adhering to the end of the egg. Upon touching water this expands as before mentioned.

Larva: The very young larvæ are pure white and very active. In hatching they increase their length about twice, so that they measure 1.5 to 1.6 millimeters when they emerge. Length of full-grown larva, 7.5 to 8 millimeters. (Pl. VIII, fig. 3.) It is dark gray, the eye-spots being nearly black. The head is subspheroid, being slightly subtriangular anteriorly. The antennæ are one-half as long as the head, slightly curved. The first segment is spinous on the outer convex surface and around its entire basal area. At a point two-thirds the distance from the base is a small tubercular shoulder or notch upon which grows a cluster of about 24 to 26 pectinate setæ, each one of which is more than one-half of the length of the entire antennæ.

These setæ, in living specimens, are spread out in the form of a fan (Pl. VIII, fig. 4), but may be closed up voluntarily by the insect when it is not feeding. Four simple bristles project from the apex of the first segment, located two on either side of the base of the second segment.

Six groups of pectinate bristles are found across the frontal area, one at the base of each antenna containing twelve branches and four submedian of six and eight branches, those with eight being nearer the median line.

Mediad to each eye-spot is a simple and a trifid seta.

A row of simple, bifid and trifid bristles extends across the anterior area of the thorax.

Slightly dorsad to each of the middle pseudopoda is a minute, plumose bristle. The posterior pseudopoda are well developed. Dorsad to these are numerous pectinate bristles in a single cluster on a slight tubercle, while the fore, mid and posterior pseudopoda are provided with clusters of long, pectinate setæ.

Lateral, pectinate bristles grow from the first and fourth abdominal segments, two or three on each tubercle, those on the first and second segments curving anteriorly. Numerous other simple or tiny plumose setæ are found upon the remaining segments.

The eighth abdominal segment is two-thirds the length of the four preceding (Pl. VIII, fig. 5.) The respiratory siphon, which is twice the length of the eighth segment, is completely chitinous and is usually held at an angle of nearly 90° to the longitudinal axis of the body. Upon its ventral surface it has four groups of 5- or 6-parted pectinate bristles, situated about midway from base to apex, and another group composed of four short bristles half-way from the last of these to the apex; dorsally a single bristle two-thirds distant from the base. The pecten is composed of eight to eleven scales according to the individual specimen. These scales are quite similar in shape to those of *Culex restuans* Theob., delineated by Felt,[13] except that one tooth is much longer than any of the others.

The lateral comb of the eighth segment is composed of about forty-two scales similar in form to those of *C. lazarensis* Felt.[14]

At the base of the siphon, on the eighth segment, is a single stout bristle, ventrad to which is a group of eight pectinate setæ. At the posterior ventrolateral margin of the eighth segment, near the point of union of the ninth, is another group of six pectinate setæ.

The ninth segment bears a chitinous annular sclerite, the posterior margin of which is undulate and the posterior dorsal area of which is finely setose.

The ventral anchor bristles are in twelve groups, each of which is composed of two compound setæ. The dorsal anchor bristles are six, two of which are two and one-half times the length of the respiratory siphon.

The anal tracheal gills are of the same length as the ninth segment, taper to an acute apex and have a few irregularly placed annular spots.

The length of the larval period in *Culex fatigans* is from six to eight days.

These larvæ breed almost exclusively in rain barrels and in water tanks in houses. Another favorite place is in the large cans used for drinking water or for rain water caught from gutters. The larvæ find sufficient food in the decaying particles of nipa which wash down from thatched roofs or from the sides of rain barrels. They hang nearly vertically in the water, but they frequently feed at the surface, in which case the siphon is used as a pivot and the animal's head moves around in a circle, the body being also curved to form a half circle.

Pupa: Length over dorsum 5.5 millimeters, color light brown changing to dark brown a day before the adult emerges. The respiratory siphons are of normal shape and minutely setose externally. (Pl. VIII, fig. 6.)

The second abdominal segment bears a pair of flat, plumose setæ while those of the first segment, although plumose, have but few (six to seven) branches.

The third, fourth and fifth segments bear tiny compound setæ dorsally, those of the third and fourth being near the posterior margin, those of the fifth being discal and submedian. In addition, each segment is provided with long, simple bristles on the posterior lateral margins. On each side of the posterior margin of the eighth segment are three tiny setæ: simple, bi- and trifid respectively, extending externally from the median line.

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[13] *N. Y. State Mus. Bull.* (1904) 79, 327, fig. 71.

[14] *Idem* (1904) 79, 310, fig. 48.

The pinnuræ are subcircular, their margins being excavated internally at the base. They are devoid of cilia and are very minutely rugose or setose. The urochaetæ are very short, being less than one-tenth the length of the pinnuræ.

The pupal stage lasts two to three days.

Adult: Length, 4 to 5 millimeters. (Pl. X, fig. 1.) The general color is light brown. In perfectly fresh specimens three faint, dark brown, parallel longitudinal lines are visible on the mesothorax, but in old specimens this is less apparent, unless they are denuded.

The hair-like scales of the mesothorax are golden in certain lights. In addition, there are four well defined longitudinal rows of dark curved setæ, two submedian and two sublateral, on the mesothorax.

The abdominal segments are clothed basally with flat, pale ochraceous scales, causing the appearance of transverse banding on the abdomen.

The legs are uniformly dark brown and the proboscis, which is also dark brown, is unbanded, thereby distinguishing this species from *C. microannulatus* Theob., the only other mosquito with which it might at first sight be confounded, except the occasional *Mansonia uniformis* Theob., which may be at once distinguished, by the layman, by its brown and ochraceous, banded legs.

HABITS OF THE ADULT.

This species is a domestic form *par excellence*, breeding only in or near houses in the Philippines and causing more real annoyance than any or all other species combined. It begins its attacks at nightfall, and the pests may be seen as early as 6 o'clock, pouring into open windows and doors in cohorts. Their humming can be heard continuously in a quiet room, especially if it is closed. Hardly a district in Manila is free from these mosquitoes and they are found in all the towns near the coast that I have visited. The style of architecture prevalent in Philippine towns, where the water tanks, reservoirs, bath-tubs, cisterns, etc., are built in with the structure, and where, in later days, these receptacles remain unused or superannuated, lends itself readily to the harboring and breeding of *Culex fatigans,* and I think it can be stated that without doubt every house harbors and breeds its own supply of these pests. Invariably, when I have been called upon to visit a house especially plagued with *C. fatigans,* I have found larvæ actually breeding in plain sight in sufficient numbers to supply two such dwelling houses with adults.

Being, as they are, purely domestic, these mosquitos are amenable to such simple remedial or prophylactic measures as to render it surprising that people suffer themselves to be exposed to an annoyance and menace to health which is so easily to be prevented. In every case a few drops of petroleum placed on the surface of the water which may afterward be drawn from the bottom of the receptacle without danger of taint, or the emptying of some unused vessel, will destroy thousands of larvæ and prevent the females from depositing their ova. It seems probable that *Culex fatigans* is a carrier of filaria and a transmitter of dengue,[15] and therefore the question of its destruction carried on in a systematic and coöperative manner assumes greater importance.

The attitude of this mosquito when at rest is so characteristic and so different from that of any other species, that I have drawn a female, shown on Plate IX, fig. 2. The position of the head and proboscis, the hind legs and abdomen are especially to be noted. Both males and females assume this attitude. When a dark garment or a hat is moved or a clothes closet is opened during the day, many individuals will at once fly forth, taking to another dark recess where they may hide.

I have successfully proved in my own dwelling in Manila that there is no need to be molested by this insect, although I live almost entirely surrounded by waterways and only a few meters removed from a salt-water swamp. I seldom see a mosquito in this place, either during the day or night. I personally empty all receptacles where *Stegomyia persistans*, *S. samarensis* and *Culex fatigans* might breed, and so the only individuals that enter, and they get in only at rare intervals, are those that come from my neighbors' houses, the nearest of which is 10 or 12 meters away.

BANKSINELLA LUTEOLATERALIS Theob.

Culex luteolateralis Theob., *Mono. Culic.* (1901), **2**, 71.
————————, Giles, Handb. of Gnats (1902), 448.
————————, Giles, *Journ. Trop. Med.* (1904), **7**, 368.
————————, *Gen. Ins., Culic.* (1905), **27**, 987, 998.
Banksinella luteolateralis Theob., *Mono. Culic.* (1907), **4**, 469.

This mosquito has been found by me in but one locality in the Philippines, namely, in nearly dry, grassy ditches behind the laboratory building of the Bureau of Science in Manila.

Insects were collected in July, in the late afternoon, between 5 and 6 o'clock. Individuals of this species settle very readily upon the hand and are not very easily frightened away. Several specimens, caught by placing vials over the mosquitoes as they alighted, bit very readily.

Their larvæ have not yet been found, but some females placed in captivity laid a few eggs separately upon the surface of the water, always near the edge of the vessel in which they were confined. However, these eggs did not hatch, so nothing is known of their life history.

Egg: The egg measures 0.63 millimeter in length, is very dark brown and irregularly oval in outline, one end being slightly more acute than the other. The surface is covered with circular, flat air-cells which are very minute at the extremities and sightly larger in the middle. The form of this egg is more like that of *Stegomyia* than of *Culex*.

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[15] Ashburn and Craig: *This Journal, Sect. B.* (1907), **2**, 128.

Theobald has already taken this insect out of *Culex* and placed it in the genus indicated,[16] basing his action upon palpal and other characters.

MANSONIA ANNULIFERA Theob.

Panoplites annulifera Theob., *Mono. Culic.* (1901), 2, 183, Pl. XXX, fig. 120, text fig. 244.[17]
———— Giles, Handb. of Gnats. London (1902), 356.
Mansonia annulifera Ludlow, *Can. Ent.* (1904), 36, 299; *idem.* (1905), 37, 734.
———— Theob., *Gen. Ins., Culic.* (1905), 32.
———— Banks, *Philip. Journ. Sci.* (1906), 1, 989.

This species, like the other two of *Mansonia* reported from these Islands, is evidently very obscure in its breeding habits, as nothing has been recorded with reference to it.

It is fairly common in certain localities in the Philippines, especially near Manila, and it is only a question of time when its breeding places and habits will be known.

A female captured at night on September 12, 1906, laid eggs on the same night on the edge of the water in the vessel in which she was confined.

Egg:. The egg, when recently laid, is pale buff colored, measures 0.82 millimeter in length and at one end has a very narrow neck like a bottle. The surface is finely granulated and at the neck end are numerous flat, circular air chambers as shown on Plate X, fig. 3.

These eggs float horizontally upon the surface of the water, near the side of the vessel.

The adults of this species have never been found by me to bite or act as if desirous of biting, although the habit possessed by its near relative *Mansonia uniformis* Theob. is probably to be attributed to this species also.

MANSONIA UNIFORMIS Theob.

Panoplites uniformis Theob., *Mono. Culic.* (1901), 2, 180.
Mansonia africanus Theob., *Ibid.* (1901), 2, 187.
———— australianis Giles, Handb. of Gnats. London (1902), 355.
Panoplites uniformis Giles, *Ibid.*, 253.
Mansonia uniformis Ludlow, *Can. Ent.* (1905), 37, 134.
———— Banks, *Philip. Journ. Sci.* (1906), 1, 989.

Nothing is as yet known of the life history of this very abundant species, but some interesting observations have been made concerning the females. They are rather sluggish in flight and are not easily alarmed when seeking to bite a person. These mosquitoes begin to enter dwellings which are situated near forests about dusk and may continue to be annoying until 11 or 12 o'clock at night. In the field they begin to bite as soon as it is sufficiently dark to prevent their being seen except in profile against the sky. The sting is very sharp, but it lasts only for a short time as compared with that of *Culex fatigans* Wied., or *Stegomyia persistans* Banks. It is almost impossible for these insects to fly when they are filled with blood; indeed, it is with difficulty that they can lift themselves from the surface upon which they are standing.

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[16] *Mono. Culic.* (1907), 4, 469.

[17] This reads, "text fig. 224" in *This Journal* (1906), 1, 989, in error.

At Los Baños, La Laguna Province, on the evening of February 23, 1908, I captured two females of *Mansonia uniformis* Theob., one of which was infested with 7 mites and the other with 1; these were clinging to the abdomen. These mites probably belong to the family *Trombiidæ.* As the forms were all young, it is impossible to identify them, but I hope to find the adults and thus be able to place the species to which they belong. As the mosquitoes were captured when it was nearly dark and at random, and as two out of three captured were infested, it is reasonable to suppose that this is a common parasite for this mosquito. Very few mosquitoes are known to have parasites, at least in the adult stage. The parasites in question measure 0.5 millimeter in length and are of a pale vermilion, retaining this color even after two months in formalin-alcohol. The individuals, in these cases, were found adhering by the proboscis to the abdominal sutures and in drying remained attached to the host.

It is my opinion that *Mansonia uniformis* Theob. may play an equally important rôle in the transmission of dengue fever as does *Culex fatigans* Wied., even if the latter be fixed upon conclusively [18] as a transmitter. This mosquito has been reported from all the points in the Philippines where dengue has occurred among American soldiers as an epidemic during the last few years.

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[18] Ashburn and Craig: *This Journal, Sect. B.* (1907), 2, 128.

LIST OF ILLUSTRATIONS.

PLATE I.

FIG. 1. Egg of *Worcesteria grata* Banks.
    (*a*) Showing granular nature.
    (*b*) Showing difference in size of granules.
    (*c*) Showing structure of single granule.
    (*d*) Showing manner of rupture of shell upon hatching of larva.
  2. Full-grown larva of same.
  3. Eighth and ninth abdominal segments of larva showing setæ and respiratory siphon.
  4. Pupa of *W. grata* Banks, showing pinnura enlarged at (*a*).

PLATE II.

Adult male of *W. grata* Banks.

PLATE III.

Adult female of same.

PLATE IV.

FIG. 1. Egg of *Desvoidya joloensis* Ludlow showing reticulation and air cell pattern.
  2. Full-grown larva of same.
  3. Eighth and ninth abdominal segments of larva showing setæ and respiratory siphon.
  4. Pinnura of pupa showing urochaeta curved at base.

PLATE V.

Adult male of *Stegomyia persistans* Banks.

PLATE VI.

Adult female of same.

PLATE VII.

FIG. 1. Egg of *Stegomyia samarensis*.
  2. Larva of same.
  3. Eighth and ninth abdominal segments of larva showing setæ and respiratory siphon.

PLATE VIII.

FIG. 1. Egg raft of *Culex fatigans* Wied.
  2. Single eggs showing cap at base, reticulation of shell, mode of floating on water and appearance after larva has emerged.
  3. Full-grown larva of same.
  4. Position of larva at surface of water.
  5. Eighth and ninth abdominal segments of larva showing setæ and respiratory siphon.
  6. Pupa of *C. fatigans* in natural position.

PLATE IX.

Diagram of eighteen egg rafts of *Culex fatigans* Wied., laid in a single night in a jar in laboratory, showing relative lengths of the egg rows.

PLATE X.

FIG. 1. Adult female of *Culex fatigans* Wied.
2. Adult female of *Culex fatigans* Wied. in resting position.
3. Egg of *Mansonia annulifera* Theob., showing peculiar shape and large air cells near neck.

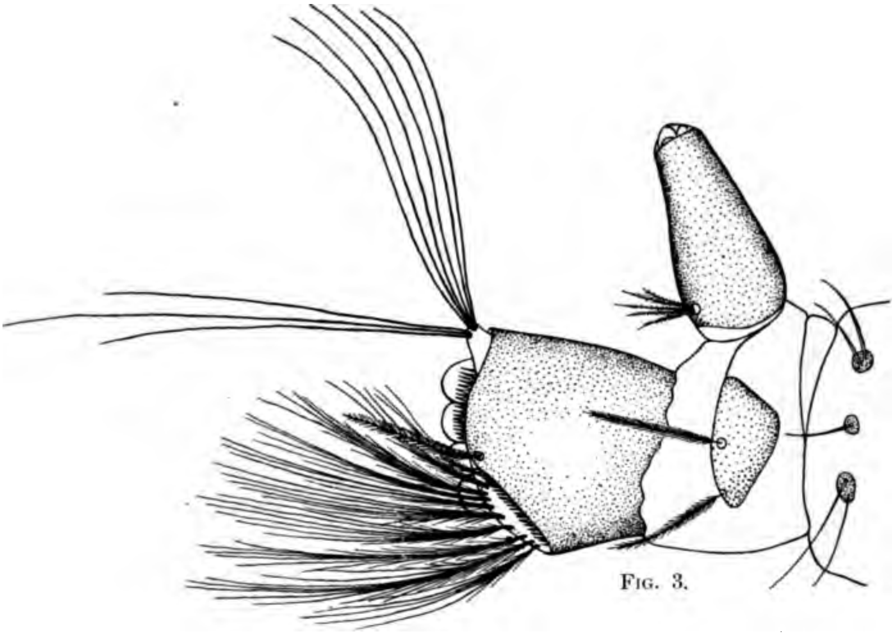

FIG. 3.

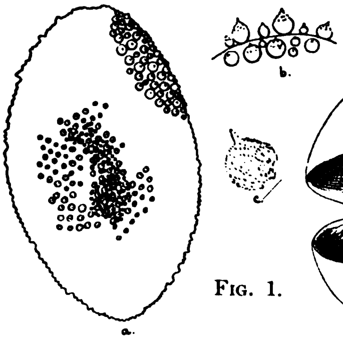

FIG. 1.

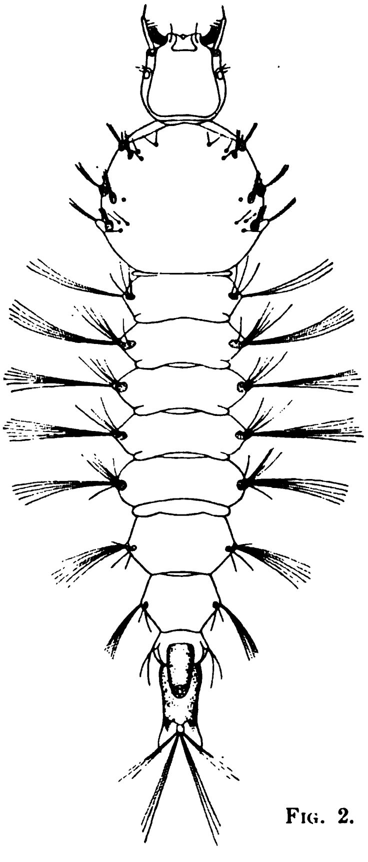

FIG. 2.

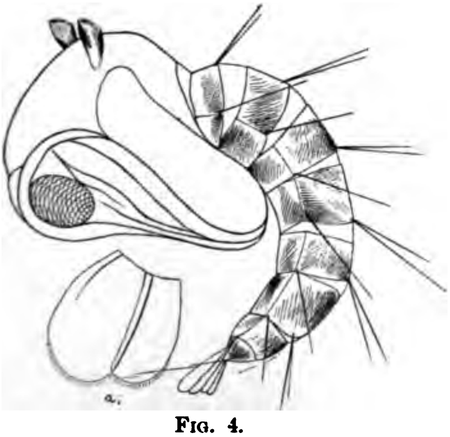

FIG. 4.

PLATE I.

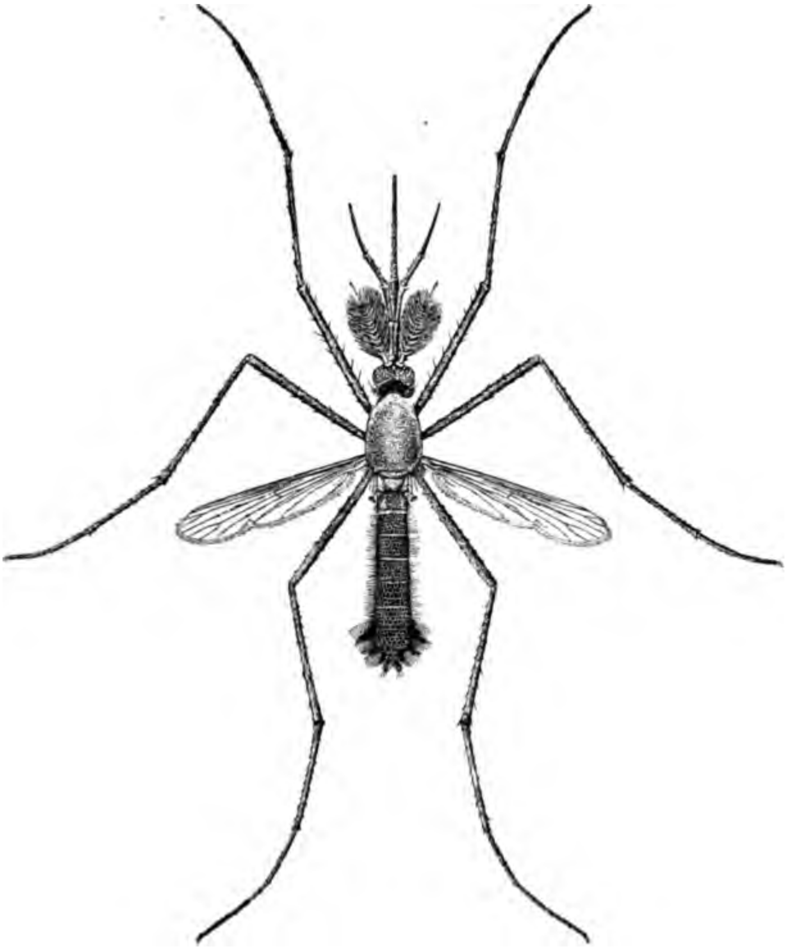

PLATE II.

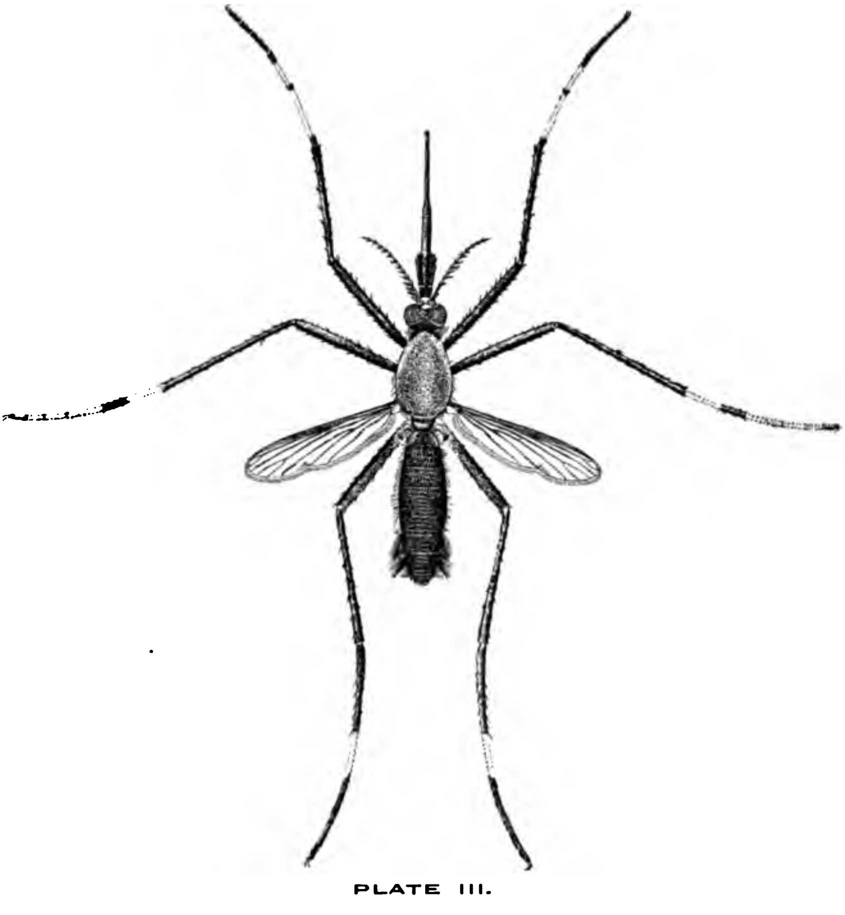

PLATE III.

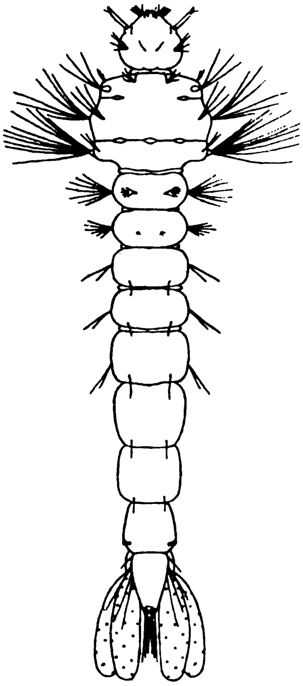

FIG. 2.

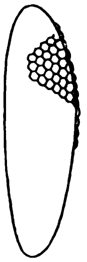

FIG. 1.

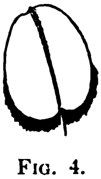

FIG. 4.

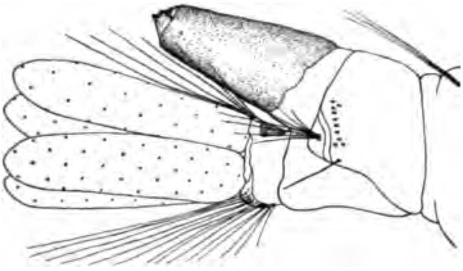

FIG. 3.

PLATE IV.

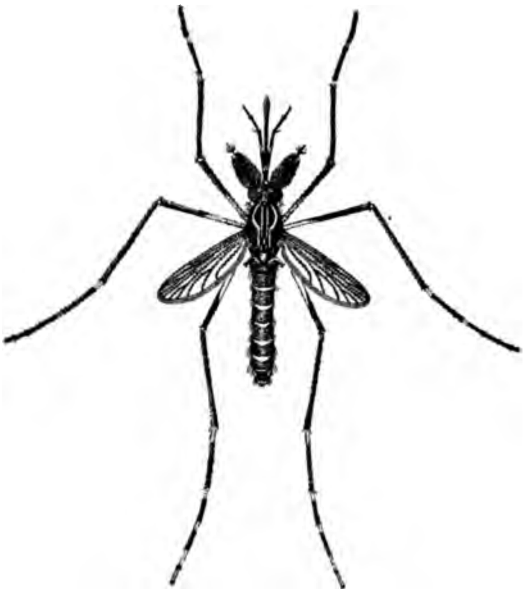

PLATE V.

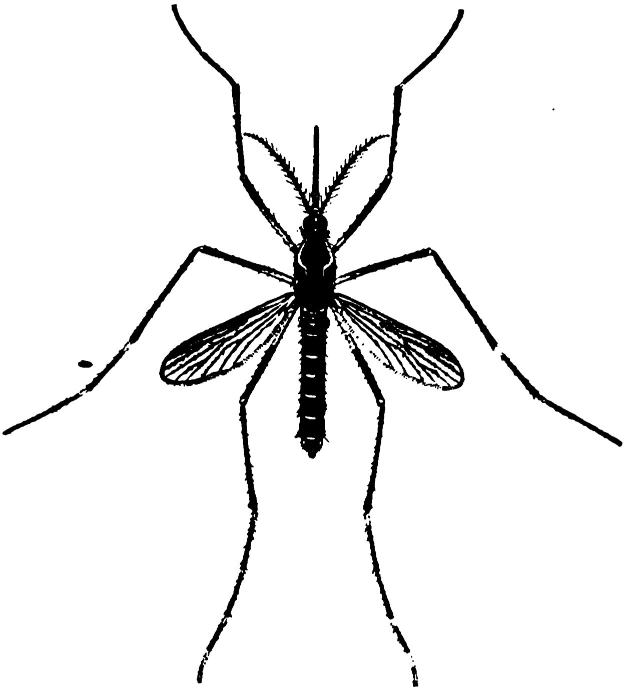

PLATE VI.

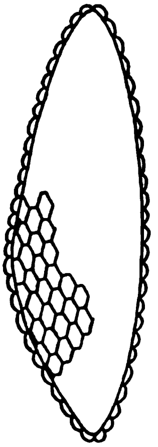

FIG. 1.

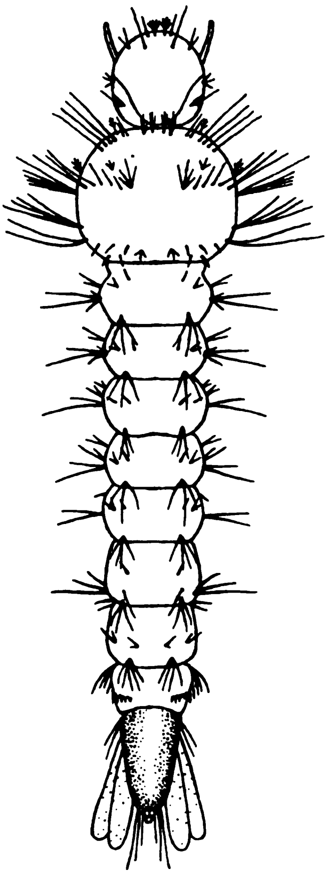

FIG. 2.

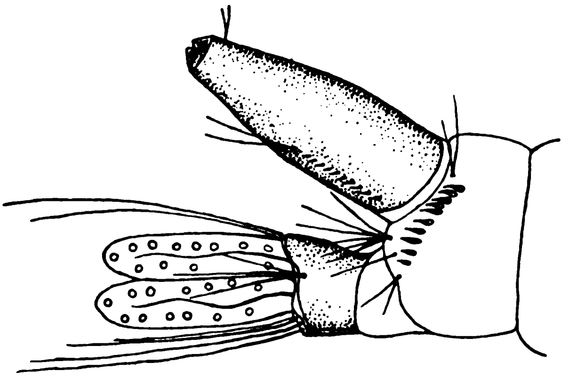

FIG. 3.

PLATE VII.

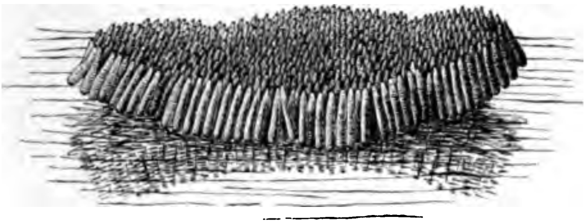

FIG. 1.

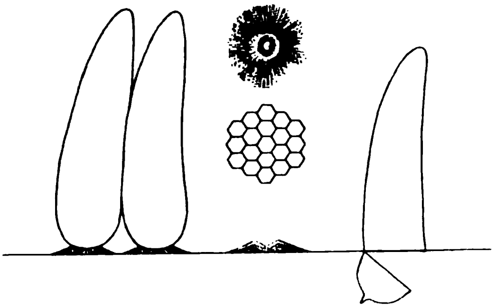

FIG. 2.

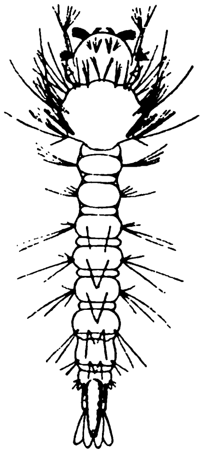

FIG. 3.

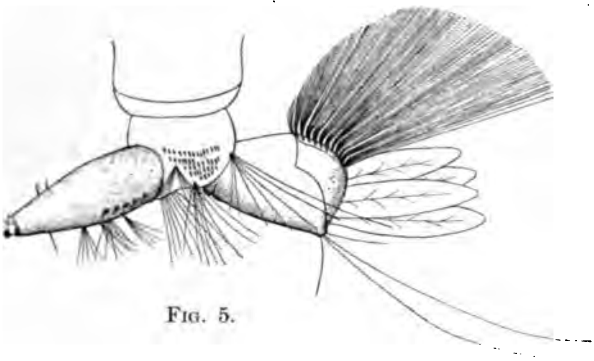

FIG. 5.

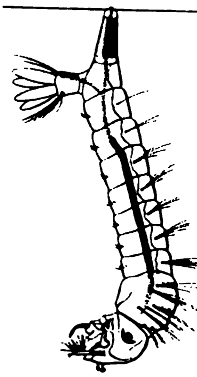

FIG. 4.

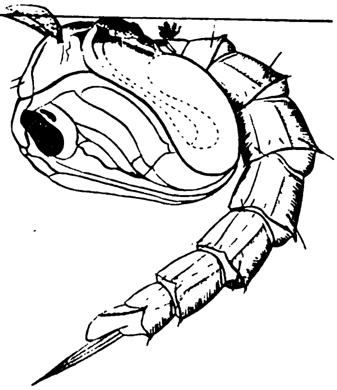

FIG. 6.

PLATE VIII.

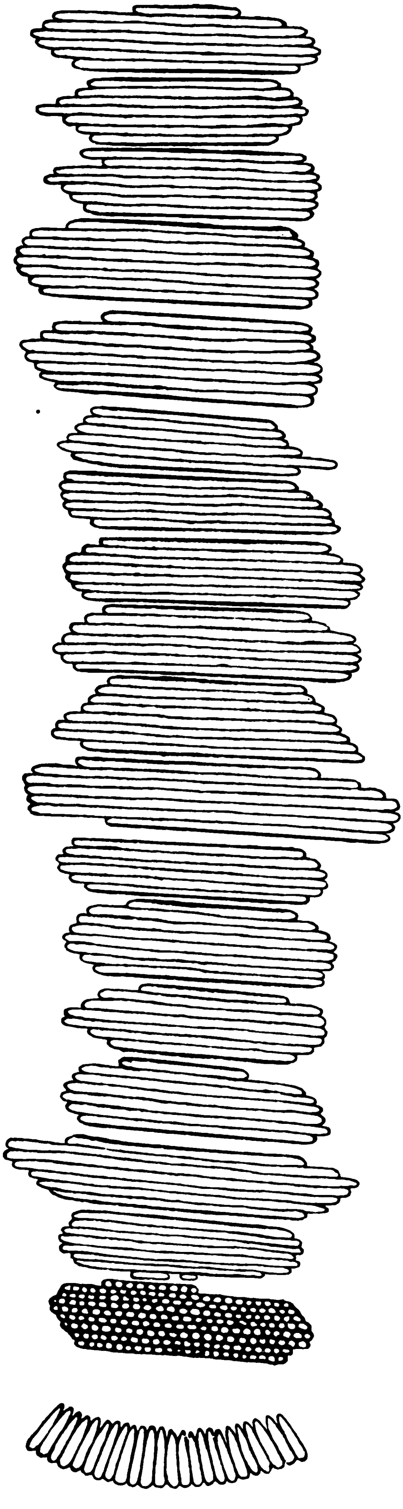

PLATE IX.

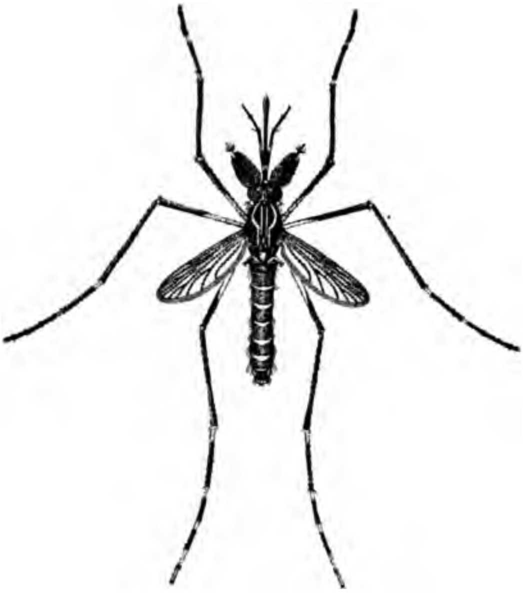

PLATE V.

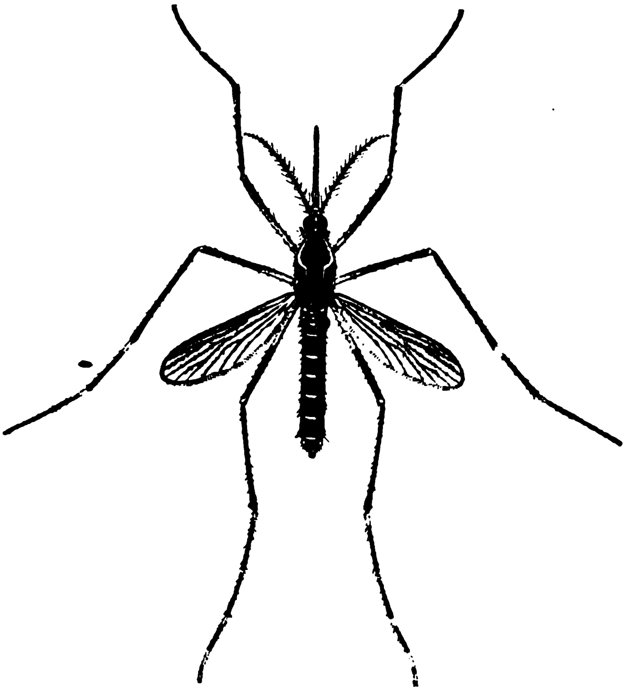

PLATE VI.

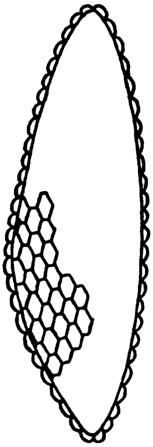

FIG. 1.

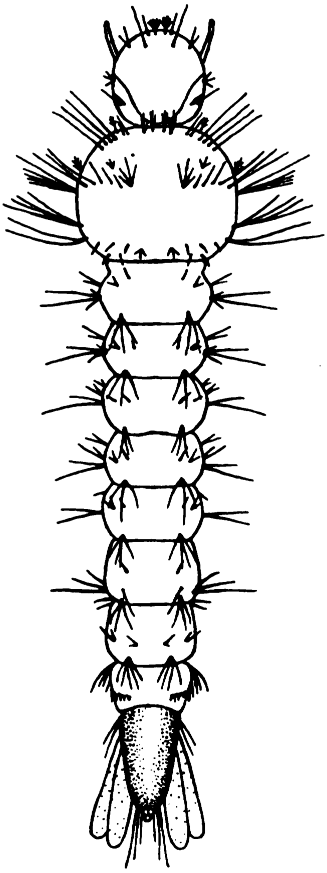

FIG. 2.

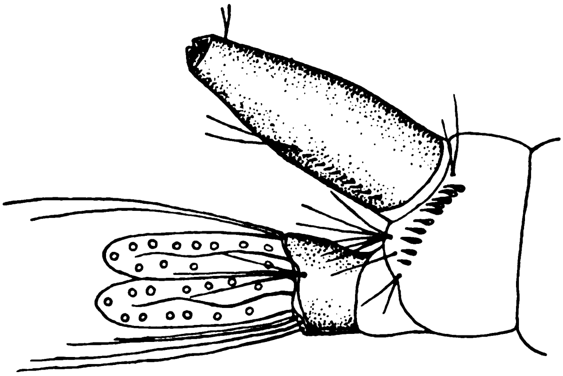

FIG. 3.

PLATE VII.

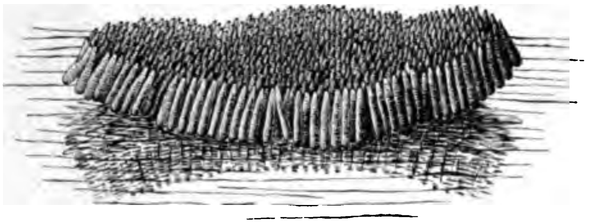

FIG. 1.

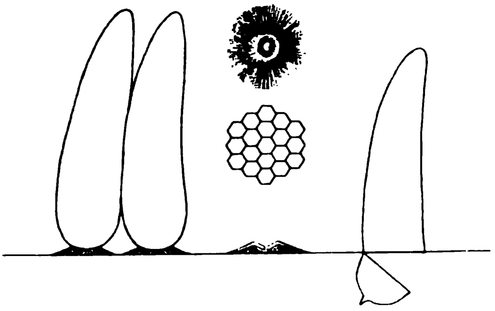

FIG. 2.

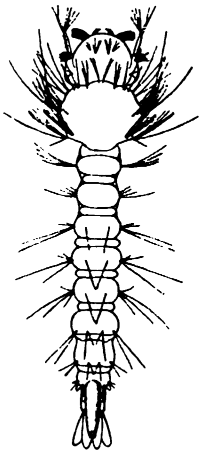

FIG. 3.

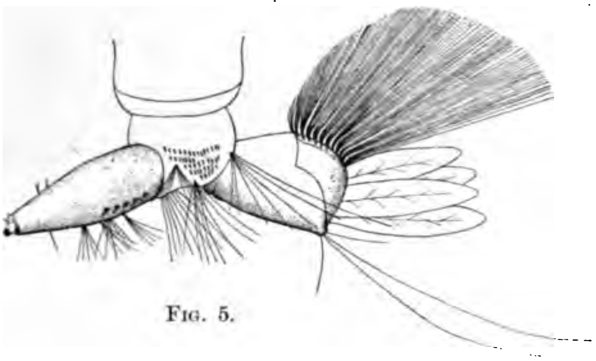

FIG. 5.

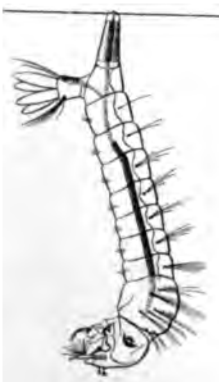

FIG. 4.

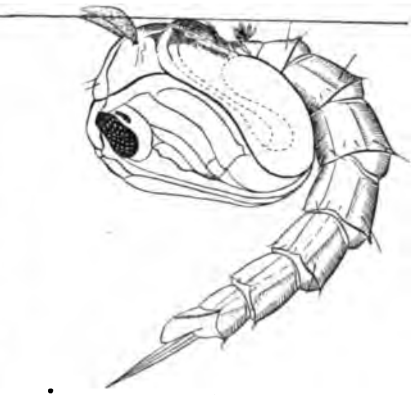

FIG. 6.

PLATE VIII.

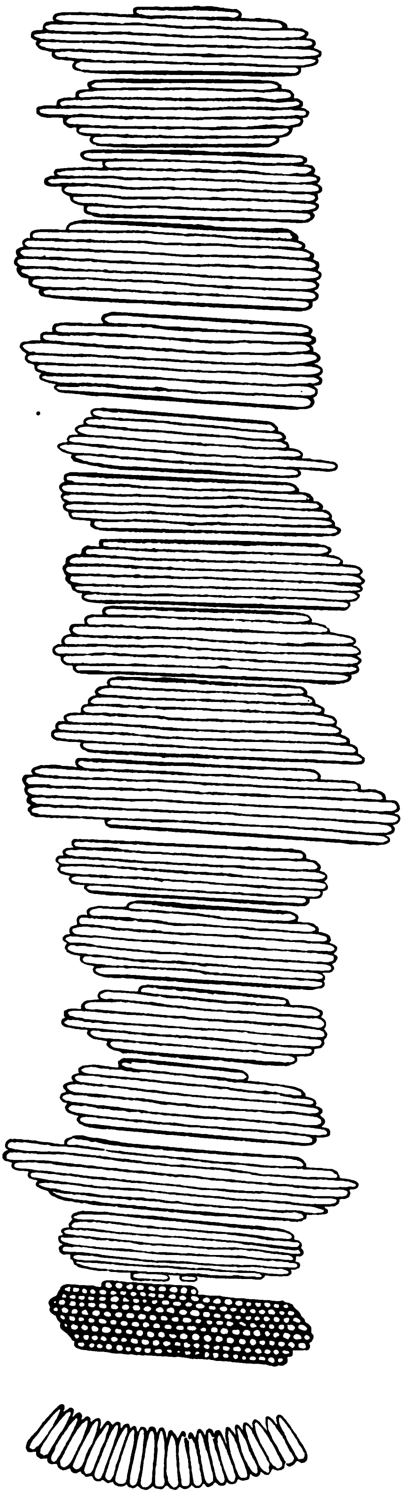

PLATE IX.

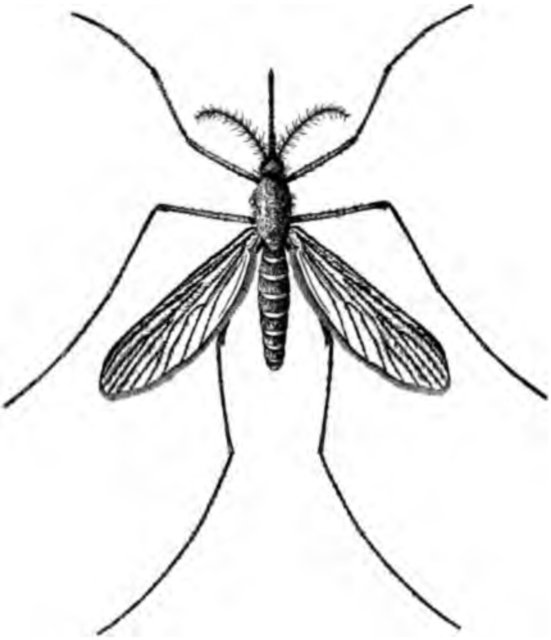

FIG. 1.

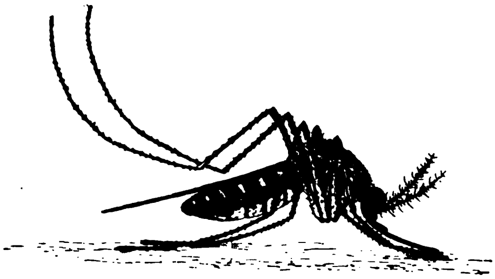

FIG. 2.

FIG. 3.

PLATE X.

DESCRIPTION OF NEW CASSIDIDÆ OF THE PHILIPPINE ISLANDS.

By J. WEISE.
(Berlin, Germany.)

Prioptera schultzei sp. nov.

Subrotundata, nigra, nitida, elytrorum disco saturate brunneo-rufo, parum nitido, fortiter subrugoso-punctato, bicarinato, uni-foveolato, antice leviter gibboso. Long. 11–12 mm.

Bongabon, Mindoro, P. I.

Time of capture: January, 1908. (W. Schultze, collector.) No. 8383 in Entomological collection, Bureau of Science, Manila, P. I.

Belongs to the species which have a large pit on the elytra and is distinguished not alone by its very peculiar coloring, but also by the coarse and wrinkled punctuation of its elytra.

Deep black, glossy, the inner edge of the epipleuræ and a narrow indistinct marginal stripe of the abdomen reddish, discal part of the elytra decidedly brownish-red and not very glossy. Front, thorax, scutellum and the lateral slope of the elytra are nearly smooth. The latter has a broad ridge in the middle and is divided from the discal part by a row of coarse punctures, which are behind the middle, pitlike, and divided by cross ridges. The thorax has a slight, flat medial groove, which runs posteriorly into a pit before the middle lobe. The elytra are a very little broader at the base than the thorax, enlarged slightly in the first quarter and smoothly rounded, then less so up to the last third and nearly straight; beyond that they are abruptly narrowed, running also nearly straight into the sharply pointed apex. The basal triangle extends to a low, united, uneven cross ridge, and is separated by the first longitudinal ridge, which in common with the second larger one surrounds the shallow pit on the discal part behind the cross ridge.

This interesting species is named in honor of Mr. W. Schultze of Manila, who found it in all stages of development on the coast of Mindoro.

Cassida (Odontionycha) picifrons sp. nov.

Breviter ovalis, convexiuscula, dilute viridi- vel testaceo-flava, nitida, antennis testaceis apice leviter infuscatis, capite piceo, fascia lata metasterni nigra, ventre in medio infuscato, elytris punctato-striatis, protecto modice explanato, sat deflexo, sat crebre punctato. Long. 3.5–4 mm.

Manila, P. I.

Time of capture: January, 1908. (W. Schultze, collector.) No. 8619 in Entomological collection, Bureau of Science, Manila, P. I.

This species is closely related to the East Asiatic *C. obtusata* Bohem., but is not so broadly built and is easily distinguished by its darker head.

Broad-oval shaped, slightly arched, glossy pale greenish-yellow, or on the discal part of the upper side light brownish-yellow, the lateral slant lighter, greenish or yellowish. Antennæ reddish-yellow-brown, the last joints broad and slightly darkened. Head pitch-brown, front nearly smooth, the anterior margin evenly rounded (♂), or drawn forward above the head a little, the corners small, rounded and situated at about two-thirds of the whole length. Elytra at the base slightly rounded, the somewhat acute shoulders a little broader than the thorax, the posterior portion slightly widened, then curved, posteriorly strongly narrowed and the apices uniformly rounded. The discal part punctate-striate, with a few regular, somewhat raised intermediate striae, the slanting part not so closely and deeply punctate as the striae. The under side and legs of a similar color to that of the upper side. Metathorax with a broad transverse black stripe. The middle of the abdomen and especially toward the anterior half of it blackish diffused.

LIFE HISTORIES OF SOME PHILIPPINE CASSIDIDÆ.

By W. Schultze.

(*From the Entomological Section, Biological Laboratory, Bureau of Science, Manila, P. I.*)

INTRODUCTION.

During the months of November and December, 1907, my attention was attracted by the abundant appearance of certain species of *Cassididæ* on plants in the vicinity of Manila. This opportunity as well as the interesting accounts of this family by Muir and Sharp[1] induced me to work out some life histories of Philippine *Cassididæ*. I wish to express my thanks to Mr. J. Weise, Berlin, who was so kind as to identify the species described in this paper.

PRIOPTERA SINUATA Oliv. (Pl. VI, fig. 2).

Prioptera sinuata Oliv., *Encyl. Méth.*, (1790) *V*, 392.

Egg: The eggs are always laid singly on the underside of the leaves. The female at first deposits a thin layer of a gelatinous substance upon the leaf, and this, coming in contact with the air, dries very quickly. She then lays her eggs upon this substance and covers them with another, very thin, gelatinous layer. The egg is thus inclosed in a flat, semitransparent case. (Pl. I, fig. 1.) An irregular, roof-like cover is placed over the whole length of the primary case, fastened to the egg-case by one end only, the latter being pointed. This upper layer has an undulating structure. (Pl. I, fig. 2.) In the majority of cases,[2] a few particles of excrement are found on the upper cover.

Larva: The young larva of *P. sinuata* Oliv., when newly hatched, is yellowish, the head light brown; later, but before the first molt, the general color becomes light brown; head, black; the chitinous plates on the prothoracic segment and the two large subanal spikes also black. The larva has eight dull-pointed, curved and fleshy spines on the prothoracic and two short tubercles and two curved spines on each of the meso- and metathoracic segments; first to sixth abdominal segments, each

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[1] *Trans. Ent. Soc.* London, (1904), 1–21, pls. 1–5.

[2] My statement is based upon the observation of about 250 egg-cases of this species.

toward the anal segment, as in the larval stage. The whole dorsal surface of the pupa is covered with numerous, small tubercles. The stigmata are of moderate length.

This species feeds on *Premna vestita* Schauer.

PRIOPTERA SCHULTZEI Weise (Pl. VI, fig. 1).

Prioptera schultzei Weise, *Philip. Journ. Sci.* (1908), **3**, 269.

The egg-case of this species (Pl. I, fig. 6) contains, as in *P. sinuata* Oliv., only one egg and is somewhat similar in general appearance to that of the species just described. It consists of a primary layer fastened to the leaf, on which the egg is laid; it has an irregular, thin, flattish cover over the whole with a curiously shaped, longitudinal bar fastened on top of it. This longitudinal bar is pointed at one end and on the other it runs out into several irregular, flat appendices. Laterally it has a number of broad, raised crossbars. The whole structure reminds one of the shape of the vertebral column. Some particles of excrement are found on the egg-case.

Larva: The larva of *P. schultzei* Weise (Pl. I, fig. 7) differs from that of *P. sinuata* Oliv. in the following respects. The forked spines on the prothoracic segment are straight and nearly perpendicular to each other; other spines on the pro-, meso- and metathoracic segments are straight, being unlike those of *P. sinuata* Oliv. The latter species also has the first pair of spines on the meso- and metathoracic segments developed only as short tubercles; in *P. schultzei* Weise, these spines are well developed, straight, and nearly as long as the second pair. In *P. sinuata* Oliv. the large subanal spines are curved in a peculiar way (Pl. I, fig. 5, larval skin on pupa), although in *P. schultzei* Weise they are curved to form a loop coming in contact at the middle and then recurved again. (Pl. I, fig. 8.) The excremental shield of the larva of this species, although in structure very similar to that of *P. sinuata* Oliv., is much more solid, the long filaments more regularly arranged, and, as a whole, the shield is more nearly circular. The color of this shield is not black, as in the former species, but, with reference to age, older excremental filaments are darker gray than younger ones, which are sometimes even whitish. Shortly before pupating, the larva casts off the excremental shield and as in *P. sinuata* Oliv. only the last larval exuviæ remain on the pupa. (Pl. I, fig. 8.) The latter differs from that of *P. sinuata* Oliv. in the following details: tubercles on the pronotum not as strongly pronounced and shorter; flat, spatulate hooks on the first and second abdominal segments larger and more sharply curved; the pair on the third segment very long and narrow, pointed, triangular and bent toward the anal segment; the general color of the pupa is porcelain-white, mesonotum light brown; two small light-brown spots occur on the pronotum and fourth abdominal segment, and two large, black spots on the metanotum and on each of the second and third segments.

I found this species feeding on *Premna integrifolia* Linn. on a dry and sandy beach, near Bongabon on the east coast of Mindoro, P. I., in the month of January, 1908, in all stages and quite numerous.

ASPIDOMORPHA MILIARIS Fabr. (Pl. VI, fig. 6).
Aspidomorpha miliaris Fabr., *Syst. Ent.*, (1775), 91.

Egg: The egg-case of *A. miliaris* Fabr. (Pl. III, fig. 1) is a very remarkable and complete structure, similar to that of *A. puncticosta* Bohem., and the latter is so well described by Muir[3] that it is not necessary for me to repeat his statements concerning the process and manner by which the oötheca is built up. However, I found that the egg-clusters of *A. miliaris* Fabr. differ greatly in size and in the number of eggs which they contain. The number of eggs in one oötheca varies from 32 to 80.[4] All oötheca which I observed have eight longitudinal rows of cells. The four middle rows contain the eggs; the others, two rows on each side, being air chambers. The complicated structure of the egg-case of *A. miliaris* Fabr. alone, indicates that this species is much more advanced in its development than its near relatives.

Larva: Larvæ of *A. miliaris* Fabr. always live in groups or communities and they pupate together. The newly hatched larva of *A. miliaris* Fabr. is light ochraceous-brown. In this species, also, the subanal spines are extremely long. The larva has eight spines on the pro-, four on the meso-, and four on the metathoracic segments; abdominal segments each with two spines. All the spines are nearly straight, those on the seventh, eighth and ninth segments are longer than the others, and the forked subanal spines on the ninth segment are curved. Numbers of white spinules occur on all spines. The color of the spines is dark, with lighter-brown toward the base. Head and legs are also dark brown, lighter along the sutures. The general color of the larva (Pl. III, figs. 2 and 3) is creamy-white, but toward the margins and segmental articulations ochraceous. On the prothoracic segment, indications of a chitinous sclerite appear, marked with two irregular, dark-brown spots. The mesothoracic segment has two black antemedial and two brown submarginal spots; metathoracic segments with two large, black antemedial, four smaller, submarginal brown spots, and one small, black, nearly round, medial spot on the posterior half of the segment. First to seventh abdominal segments, each with two irregular, oblong, black antemedial, two submarginal, and one small nearly round medial spot, the latter on the posterior half of each segment. The seventh

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[3] *loc. cit.*, p. 2.

[4] Observation of 16 egg clusters.

segment has two medial spots. All spots are arranged in longitudinal rows. Stigmata white and of moderate length. The larvæ of *A. miliaris* Fabr., when feeding, place themselves in a single row close together along the margin of the leaf; however, when resting, they form an oval figure all heads being directed toward the center. (Pl. II.) The exuviæ are carried perpendicularly to the body. The habit of pasting the particles of excrement on the exuviæ is still indicated in this species, as the larva puts its filaments very loosely on the last exuviæ, but these filaments fall off at the slightest motion of the larva. The full grown larva, about two days before it pupates, fastens itself upon the leaf with a glutinous substance generally head downwards. Only the fifth larval skin remains on the pupa. During the pupal stage, as in the larval, the individuals remain in groups. (Pl. IV.)

LIFE HISTORY.

	1907.		1907.
Eggs laid	November 5	Third molt	November 24
Eggs hatched	November 15	Fourth molt	November 28
First molt	November 17	Pupated	December 8
Second molt	November 21	Adults emerged	December 13

Pupa (Pl. III, fig. 4): Yellowish-ochraceous, two black spots at the posterior margin of the pronotum and two antemedial spots on each of the first and second abdominal segments. The pronotum of the pupa is about twice as broad as long; marginal area semitransparent and with four short, dark brown hooks in front. The spines on the first to the fifth abdominal segments of the larva are developed in the pupa into flat, semitransparent leaflets prolonged laterally into a black spine. All other spines of the larval stage are absent in the pupal. Stigmata of moderate length. The food plants of *A. miliaris* Fabr. are *Calonyction bona-nox* Boyer, *Ipomœa triloba* L., and *Ipomœa pes-capræ* (L.) Roth.

Adults: The adults of *A. miliaris* Fabr. (Pl. VI, figs. 6–9) are extremely variable, with reference to coloring. Fig. 6 represents the most common form. The direction in which the change of coloring takes place is as follows: the black spots become enlarged and connected by longitudinal or transverse bars. (Pl. VI, figs. 7 and 8.) The variation shown in fig. 9 is a rare form. In this the central portions of the elytra are entirely black. Whether or not these variations are due to seasonal dimorphism must be left for further research.

I have noticed instances of very peculiar behavior on the part of all species which were closely observed. In the act of copulation, the female puts the fore and middle legs close together, attempting by strong, sidewise motions to shake the male off. It appears that by doing so, this female coquetry has the contrary result, and it suggests seduction on her part. *"Cum finis est licitus, etiam media sunt licita."*

CASSIDA PICIFRONS Weise (Pl. VI, fig. 3).

Cassida (Odontionycha) picifrons Weise, *This Journal*, current number.

Egg (Pl. III, fig. 5): in a thin primary case, fastened to the leaf by a very thin, semitransparent and smooth cover. The eggs are laid singly, rarely in pairs, but always under an individual cover, on the underside of the leaf. Usually some particles of excrement are found on the cover.

Larva: The young larva very much resembles that of *M. trivittata* Fabr., not alone in shape, but also in its behavior, as it places its excrement in a like manner on the long, subanal spines, but forming a more irregular and loose lump than that of *M. trivittata* Fabr. The very young larva is yellowish-white, later the color becomes light green and as the skin appears transparent, the different organs are visible as lighter or darker markings. The first pairs of inner spines of the prothoracic segment are curved, the others straight and all of about the same length. The first pair on the meso- and metathoracic segments are two-thirds the length of the second pair, which are as long as those on the prothoracic segment; spines of the first to fifth abdominal segments smaller than the former, decreasing in length toward the latter segment. The spines on the sixth to eighth segments increase in size again, the ninth segment having the longest spines. The spines have spinules on them similar to those of *M. trivittata* Fabr. These larvæ (Pl. III, fig. 6) place their excreta loosely between the different exuviæ.

LIFE HISTORY.

	1907.		1907.
Egg laid	December 2	Third molt	December 16
Egg hatched	December 7	Fourth molt	December 20
First molt	December 10	Pupated	December 23
Second molt	December 12	Adult emerged	December 26

Pupa: The pronotum of the pupa (Pl. III, fig. 7) is not as rounded as in *M. trivittata* Fabr.; the surrounding spinules are somewhat irregular in length. First to fifth abdominal segments lamellated and surrounded by spinules. Lamellation on first to fourth segment drawn out into very long spines. Stigmata white, tracheæ[5] excrescent, the relative length of each to the other being as follows: tracheæ of first and second segments equal, one-third the length of that of the third segment; of the fourth segment twice as long as the one on the first segment and of the fifth segment but half as long as that of the third segment (1–1–3–2–1½).

This species feeds on *Amarantus spinosus* Linn.

[5] The excrescent tracheæ may prove to be very valid specific characters.

METRIONA TRIVITTATA Fabr. (Pl. VI, fig. 4).
  Metriona trivittata Fabr., *Syst. Eleuth.* (1801), 1, 397.

Egg: The egg-case of *M. trivittata* Fabr. (Pl. V, fig. 4) is somewhat similar to that of *P. sinuata* Oliv., but more perfect in its structure. It is laid on the upper or under side of the leaf and always contains a single egg. The egg itself is inclosed within a very thin primary case and the latter is placed under a remarkably perfect, roof-like cover fastened to the leaf. This cover is thin and has two nearly parallel, longitudinal carinæ, which are somewhat excurved at one end, but run together at the other end where they are bent and erect. The area between the carinæ has a semicircular impression, but the area outside of this is sloping. (Pl. V, fig. 5, diagram of cross-section.) Numerous regular, fine striæ are visible. The egg of this species is always free from any excremental covering.[6] The color of the egg-case is a very pale green.

Larva: Shortly after hatching and before feeding, the young larva expresses a kind of glutinous substance which it pastes with its long evaginating anus upon each one of the long, subanal spines in the shape of a tiny drop. Later it places the particles of its excreta upon these spots of glue, so that about twelve hours after hatching, a union is effected between the particles on the two subanal spines. The larva (Pl. V, fig. 6) disposes of its excrement in this manner only during the period from hatching to the first molt, that is, in building up a cross-bar between the two subanal spines.

The larva of *M. trivittata* Fabr. (Pl. V, fig. 7) is very flat and of a uniform green color, only the spines are somewhat lighter, the stigmata being white. The color of the larva corresponds exactly with that of the leaves of its food plant (*Ipomœa triloba* L.). The larva has thirty-two marginal and two subanal spines; the former, with the exception of the inner slightly curved ones on the first pairs, are straight. the shortest being situated on the third, fourth, fifth and sixth, the longest on the seventh abdominal segment. All of these spines are beset laterally with minute spinules. The forked subanal spines of this larva are very long, in fact even in the full-grown ones at least half as long as the whole body and two of the exuviæ are transfixed by the above-mentioned spines. In this species the exuviæ are fastened to each other in a manner similar to that in *A. miliaris* Fabr. The larvæ of *M. trivittata* Fabr. are found mostly on the upper sides of the leaves and carry their exuviæ behind them, lying flat to the leaf, but when disturbed they bend the mass up over the dorsum as a protecting shield for the body. All larval skins remain on the pupa.

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[6] Observation of about 200 eggs.

LIFE HISTORY.

	1907.		1907.
Egg laid	November 17	Third molt	December 5
Egg hatched	November 27	Fourth molt	December 9
First molt	November 30	Pupated	December 15
Second molt	December 2	Adult emerged	December 19

Pupa (Pl. V, fig. 8): Exterior line of the pronotum oval and with a marginal row of spinules of which two pairs, anteriorly, are very prominent and twice as long as the others. Lateral margins of the first to sixth abdominal segments lamellated, semitransparent and surrounded by a row of spinules of which those at the point are longer than the others, the lamellation decreasing in size toward the sixth segment. Stigmata white, tracheae slightly excrescent, but very long on the fourth segment. The pupa is of the same color as the larva. This species is the most common of those described in this paper and is found during the entire year.

LACOPTERA PHILIPPINENSIS Blanch. (Pl. VI, fig. 3).

Lacoptera philippinensis Blanch., *Voy. Pole Sud,* (1853), 4, 321, plate 18, fig. 14.

Egg: The egg (Pl. V, fig. 1) is in a thin primary case; later, under a perfect cover, fastened to the leaf. There is always a large quantity of excrement present on the central part of the cover. Its margins show numerous, regular impressions. The egg is laid on the upper and under sides of the leaves and the egg case contains only a single egg. This species differs in this respect from *Lacoptera excavata* Bohem., as Muir[7] observed that the eggs of this species were laid with from two to four in each case.

Larva: The young larva of *L. philippinensis* Blanch. is yellowish, later it turns brown, the chitinous plates on the prothoracic segment being still darker. The larva (Pl. V, fig. 2) has eight[8] spines on the prothoracic segment, two forked pairs in front being slightly curved. All the spines are irregular in shape, not straight, and have minute spinules, even the very long, subanal ones having some toward the base. This larva also uses its excrement in forming a solid flat, roughly triangular shield or cover. As in *L. excavata* Bohem., at each molt the old skin is worked into the shield, yet is not covered entirely with excrement, skins of the heads and feet of different molts still remaining visible. The larva is found most frequently on the upper side of the leaf.

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[7] *loc. cit.*, p. 8.

[8] The larva of *L. philippinensis* Blanch. differs also in this respect from *L. excavata* Bohem. as the latter species has only six spines on the prothoracic segment (Muir, *loc. cit.* Pl. V, fig. 27a).

LIFE HISTORY.

	1907.		1907.
Egg laid	November 11	Third molt	November 25
Egg hatched	November 17	Fourth molt	November 29
First molt	November 21	Pupated	December 7
Second molt	November 23	Adult emerged	December 15

Pupa: The general color of the pupa of *L. philippinensis* Blanch. (Pl. V, fig. 3) is ochraceous-brown, with a few dark-brown markings around the stigmata and on the discal areas of the segments. The pronotum has a slight incision in front and a marginal row of spinules, of which the two pairs in front are larger and more strongly developed than the others. A triangular medial area is somewhat raised, it slopes toward the outer margin, ending in two impressions toward the inner margin; the outer margin of the first to the fifth abdominal segments is lamellated, semitransparent and with a marginal row of spinules. Stigmata brown, trachæ excrescent, more so on the fourth and fifth abdominal segments. *L. philippinensis* Blanch. feeds on *Ipomœa triloba* L.

SUMMARY.

The question of the purpose of the peculiar excremental coverings, filaments or armatures arises in the study of the different stages of *Cassididæ*. Several authors have expressed their opinions. Weise mentions the excremental coverings, etc., as a shelter against draught, and Candèze considers them as a protection against enemies. I have noted the following facts bearing upon the above-mentioned theories, during the observation of a few hundred specimens of the different species: the eggs of the different species are found on the upper and under surfaces of the leaves, with the exception of those of one species (*C. picifrons* Weise), in which instance they are encountered only on the under surface; with or without excremental coverings (in two species entirely without such covering, namely, *A miliaris* Fabr. and *M. trivittata* Fabr.). It seems to me that the placing of the egg on the lower surface of the leaf would be the first protection against draft,[9] the covering being a secondary one. Again, the excremental covering would be a protection against parasites. Of all the eggs which I observed, only one, *L. philippinensis* Blanch., was infested by a parasite (*Chalcididæ*). The larva of *P. sinuata* Oliv., as well as those of *P. schultzei* Weise and *L. philippinensis* Blanch., live mostly on the upper surface of the leaf and are concealed under the excremental shield when resting, although when they move about they carry the cover in a position nearly perpendicular to the body. If molested by another insect, or by the shaking of the leaf, they bend the shield over themselves as a protection. The solid part of the shield entirely covers the abdominal segments dorsally, for

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[9] Small pieces of leaves with the eggs attached, were cut out and placed in glass dishes with covers. In the course of a day, the small fragments of leaves were perfectly dry and brittle, although the eggs hatched just the same.

the reason that the skin in this place is not as hard as on the thoracic segments, which are protected by chitinous plates. The larvæ of *A. miliaris* Fabr., which live closely together in groups, act in a slightly different way. If one is disturbed, it begins to flick with its old skins. The larvæ sitting next to it, or even the whole group, take up the motion and in unison they strive to frighten the enemy away. I have noticed this action repeatedly. The larva of *M. trivittata* Fabr., when resting, carries its old skins behind, lying flat on the leaf, but when it is moving around, they are perpendicular to the body. It also uses its old skins in a way similar to *A. miliaris* Fabr. I have applied the following test many times. The larva, when molested with a hair, tries to touch the latter with the old skins, with the intention evidently of removing the annoying object. The pupæ of *Prioptera* and *Aspidomorpha miliaris* Fabr. do not retain the old skins, but only the last one of the larval stage by which they are fastened to the leaf. The newly transformed pupæ are extremely sensitive and when touched give several sharp flicks. During the later period of the pupal stage, they do not react as easily, the reason probably being that during the early portion of this period the skin is quite soft, but during the latter part hard enough to give sufficient protection against parasites even without the old skins or shields which are retained in the other species.

The infection by parasites probably takes place during the periods of the different molts, as in those stages the larvæ are quite helpless. The larvæ of *M. trivittata* Fabr. were often infested by a fly (*Muscidae Trachinae*), the larva of which, after becoming full grown, builds its puparium inside of the larval skin of *M. trivittata* Fabr. Pupæ of *A. miliaris* Fabr. were often infested by a small *Chalcididae*,[10] as many as 150 emerging from one pupæ.

In consideration of facts concerning the usefulness of all excremental coverings, or armatures, etc., observed on the different species mentioned in this paper, the theory of Candèze seems to me credible, and I believe that the curious structures are used principally as a protection against *parasitic enemies.*

NOTE.—After my paper was in type I happened to see the following paper: "On the egg-cases and early stages of some South China Cassididæ" by J. C. Kershaw and Frederick Muir in *Trans. Ent. Soc. Lond.* (1907) p. 249. It is worth mentioning that *C. picifrons* Weise and *L. philippinensis* Blanch. differ also in their egg-laying habits from *C. obtusata* Bohem. and *L. chinensis* Fabr., as the latter species lay more than one egg under the egg cover. With reference to the summarizing sentence of Kershaw and Muir, I still believe that protection against parasitic enemies is the "*raison d'être*" for the development of the egg-cases and larval appendages.

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[10] Mr. Banks and myself observed the act of copulation on these Hymenoptera. The adult parasites make a few tiny holes in the pupal skin of the host. The males, after emerging, stand guard around each of the holes thus made, and as soon as a female comes out, the act of copulation, which is extremely short, takes place.

ILLUSTRATIONS.

PLATE I.

FIG. 1. Egg of *Prioptera sinuata* Oliv. with the upper egg-case cover removed, × 11.
2. Egg-case of *Prioptera sinuata* Oliv., × 9.
3. Larva of *Prioptera sinuata* Oliv., resting position, × 5.
4. Larva of *Prioptera sinuata* Oliv., with the excremental shield bent backward, × 5.
5. Pupa of *Prioptera sinuata* Oliv., × 5.
6. Egg-case of *Prioptera schultzei* Weise, × 10.
7. Larva of *Prioptera schultzei* Weise, × 5.
8. Pupa of *Prioptera schultzei* Weise, × 5.

PLATE II.

Groups of larvæ of *Aspidomorpha miliaris* Fabr., natural size.

PLATE III.

FIG. 1. Egg-case of *Aspidomorpha miliaris* Fabr. Lateral section, × 5.
2. Larva of *Aspidomorpha miliaris* Fabr. after fourth molt, × 5.
3. Larva of *Aspidomorpha miliaris* Fabr. shortly before pupation, × 5.
4. Pupa of *Aspidomorpha miliaris* Fabr., × 5.
5. Egg-case of *Cassida picifrons* Weise, × 10.
6. Larva of *Cassida picifrons* Weise, × 8.
7. Pupa of *Cassida picifrons* Weise, × 12.

PLATE IV.

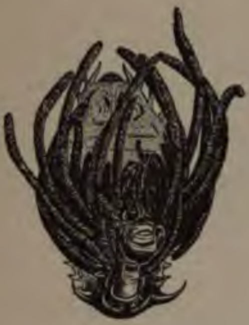
Group of pupæ of *Aspidomorpha miliaris* Fabr., natural size.

PLATE V.

FIG. 1. Egg-case of *Laccoptera philippinensis* Bohem., × 10.
2. Larva of *Laccoptera philippinensis* Bohem., × 5.
3. Pupa of *Laccoptera philippinensis* Bohem., × 5.
4. Egg-case of *Metriona trivittata* Fabr., × 10.
5. Section of the egg-case of *Metriona trivittata* Fabr.
6. Larva of *Metriona trivittata* Fabr. after first molt, × 10.
7. Larva of *Metriona trivittata* Fabr. after fourth molt, × 5.
8. Pupa of *Metriona trivittata* Fabr., × 5.

PLATE VI.

FIG. 1. ***Prioptera schultzei*** Weise, × 3.
2. ***Prioptera sinuata*** Oliv., × 3.
3. ***Laccoptera philippinensis*** Bohem., × 3.
4. ***Metriona trivittata*** Fabr., × 3.
5. ***Cassida picifrons*** Weise, × 3.
6. ***Aspidomorpha miliaris*** Fabr., × 3.
7, 8, and 9. Variations of *Aspidomorpha miliaris* Fabr., × 3.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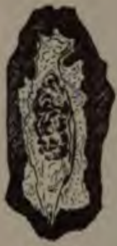
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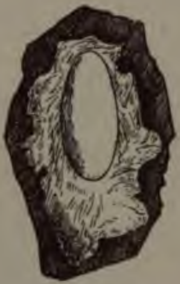
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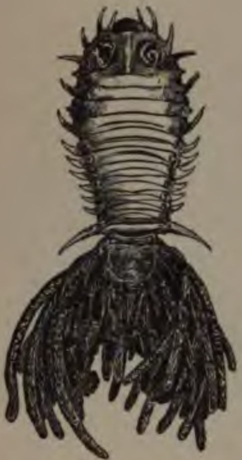
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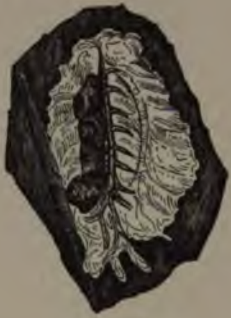
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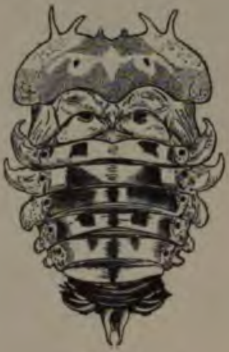
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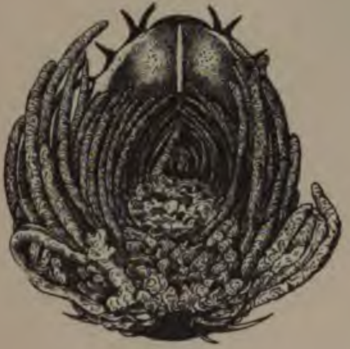
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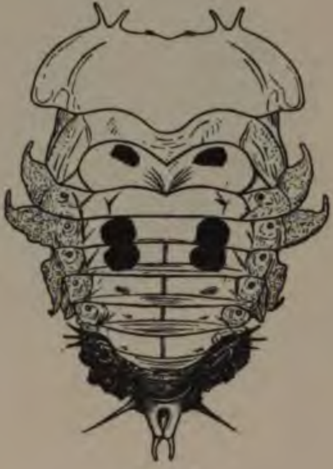
FIG. 8.

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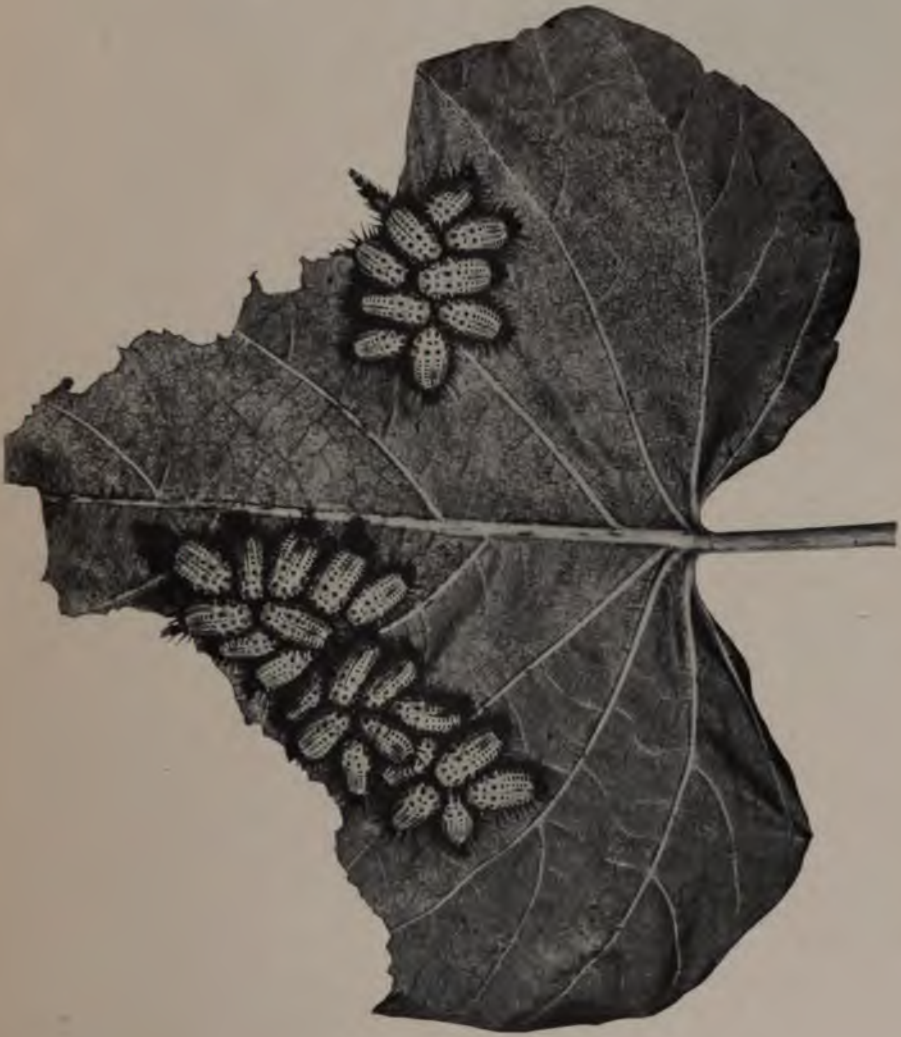

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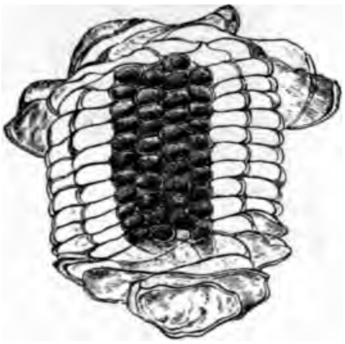

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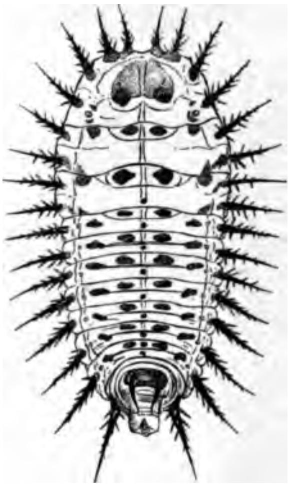

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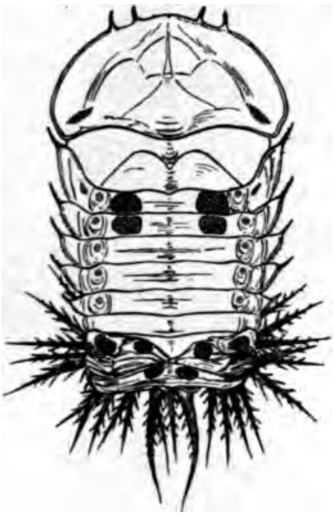

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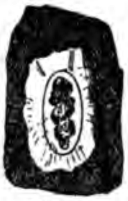

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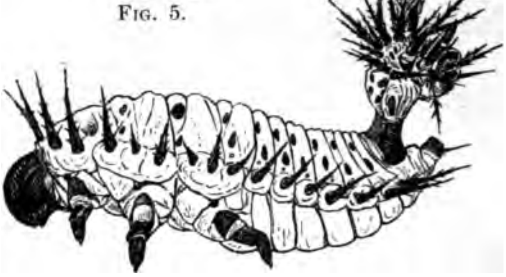

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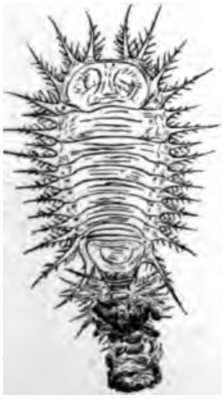

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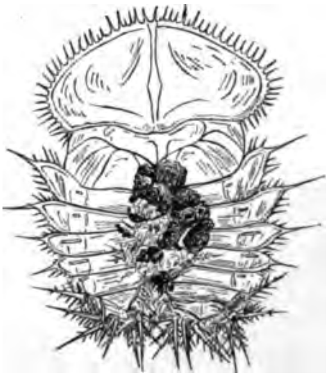

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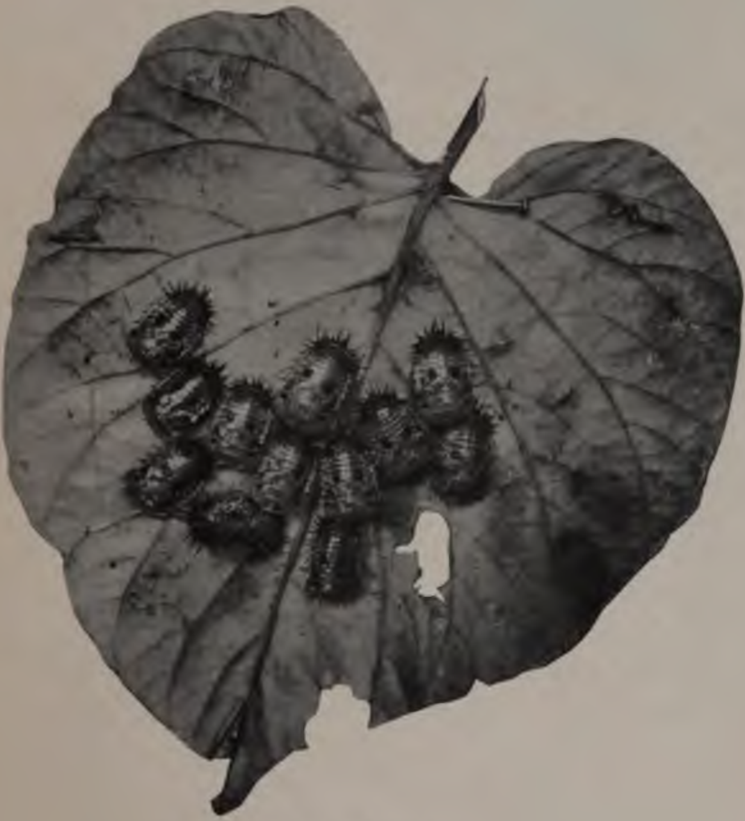

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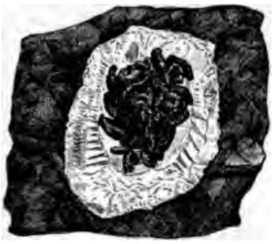

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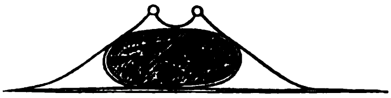

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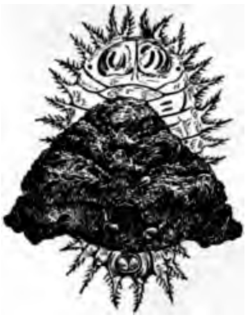

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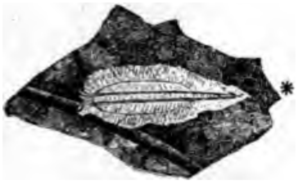

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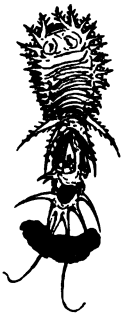

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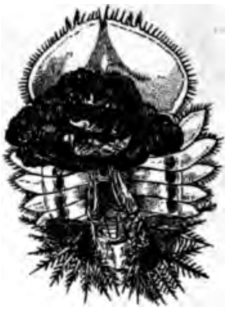

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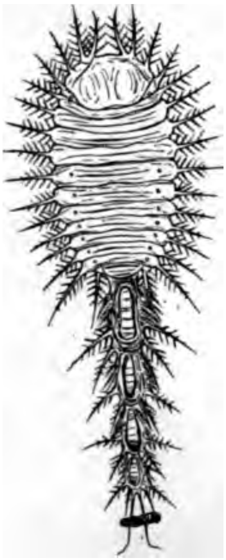

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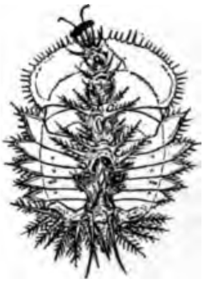

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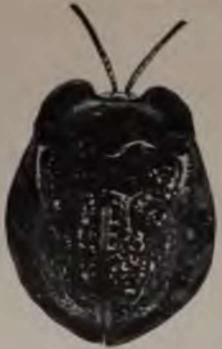

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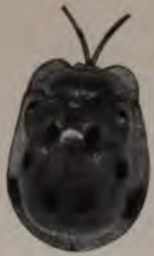

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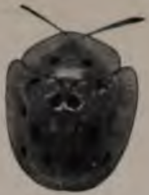

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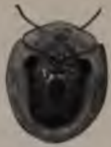

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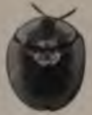

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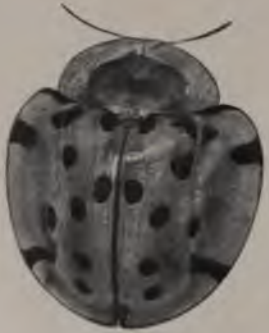

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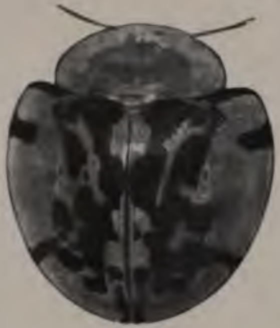

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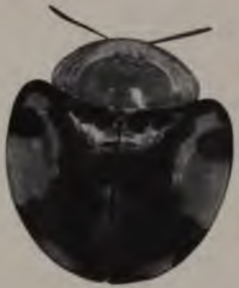

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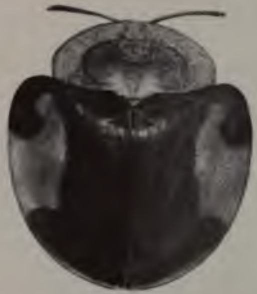

FIG. 9.

PLATE VI.

PROTHYMA SCHULTZEI, A NEW SPECIES OF PHILIPPINE CICINDELIDÆ.

By WALTHER HORN.
(*Berlin, Germany.*)

♂ *Pr. lucidicollis* Chd. parum affinis; multo major; fronte prope antennarum insertionem viridi et inter oculos maculis 2 parvis discolidalibus cyaneis aut viridibus ornata, ceteris frontis partibus et vertice et pronoto (hujus totis marginibus lateralibus et solum modo hinc inde sulcis transversis viridi-cyanescentibus) cupro-aeneo- splendentibus, elytris atro-cyaneo-purpurascentibus nitentibus, ad marginem paullo clarioribus (parte humerali marginali interdum cyaneo-viridescente); labro flavo, dente juxta-mediano acuto, mediano ceterisque 4 obtusis aut deficientibus; fronte magis excavata inter oculos, paullulum angustiore (proportione magnitudinis totius corporis!), strigis juxta-orbitalibus grossioribus; prothorace coidenter longiore, parallelo aut ante basim perparum dilatato; elytris multo longioribus, parte suturali et apicale planioribus; maculis 3 albescentibus marginalibus; humerali sat magna ut in illa, 2 cereris paullo magis a margine distantibus, media paullulum obliqua (intus et posticem versus descendente). Corpore subtus ceruleo et cyaneo, episternis interdum hinc inde violaceis; pedibus (femorum parte media aeneo-metallica, basi plus minusve testacea) et 4 primis antennarum articulis (3° et 4° interdum plus minusve testaceis), nigro-cyaneo-purpureis; palporum articulo ultimo nigricante, coxis 4 anterioribus (posticis metallicis cum apice parvo testaceo), trochanteribus flavis. Coxis posticis in disco sparsim punctato-setosis. Long. 12–14 mm.

2 ♂ ♂, Romblon Insula (Philippinae), a Dom. R. C. McGregor collecta.

Typus No. 2049 in collectione "Bureau of Science," Manilensis.

1 ♀ differt a 2 ♂ ♂ labro brunnescente, marginibus lateralibus dilutioribus, dente mediano magno ornato; pronoto ante basim perparum angustato; elytrorum apice paullo brevius rotundato paulloque minus applanato; femoribus rufo-testaceis, genis anguste metallicis; tibiis proximaliter et penultimo palporum maxillarium articulo brunnescentibus.

1 ♀ Sibuyan Insula (Philippinae), a Dom. R. C. McGregor collecta.

Typus No. 1965 in collectione "Bureau of Science," Manilensis.

There is but little resemblance at first sight, between this bright species and the little *Pr. lucidicollis* Chd., although the characters given above seem not to be so striking (we must remember that the whole genus belongs to those that are exceedingly poor in good distinctive characters!). The beautiful, red-golden color of the front and pronotum contrasts very well with the almost black-purple (shining) elytra. The large size and parallel form are equally remarkable. The fine sculpture of the front (rougher near the eyes), is longitudinal, that of the vertex and pronotum transverse, the median line of the latter is very slightly impressed, the sulcus on the base (between the free posterior margin and the posterior transverse strangulation) deep and well marked throughout. The punctures of the elytra are separated each from the other, only on the posterior third (near the suture from the middle) are they slightly confluent. Five slight, indistinct impressions are to be seen on each elytron: running down a short distance from the interior margin of the humeral spot; at the first quarter, nearer the suture than the lateral margin; anterior to the median and apical spots; and just before the apex.

The penultimate joint of the labial palpus is slightly thickened. The ♀ seems to have the prothorax slightly narrowed towards the posterior strangulation.

NOTES ON A COLLECTION OF BIRDS FROM SIQUIJOR, PHILIPPINE ISLANDS.

By RICHARD C. McGREGOR.

(From the Zoölogical Section, Biological Laboratory, Bureau of Science, Manila, P. I.)

Siquijor is a coral-rock island with an area of about 235 square kilometers; it lies in close proximity to the large Island of Negros, there being little more than 19 kilometers of water intervening between the two. As clearly explained by Worcester,[1] its birds must have come into the island during comparatively recent times and three of these have developed into well-marked representative species, namely, *Dicæum besti, Loriculus siquijorensis,* and *Iole siquijorensis.* It is also noteworthy that none of the *Megapodiidæ, Turnicidæ, Bucerotidæ, Picidæ, Dicruridæ, Sittidæ, Paridæ,* or *Timeliidæ* are known from Siquijor, although each of these families has representatives in adjacent islands.

The list of species here recorded is derived from a collection made in Siquijor by Mr. Andres Celestino, assistant collector, Bureau of Science, in September, 1907, and in April and May, 1908. There are here listed nine species not previously known from Siquijor which with the 87 species given by Worcester and Bourns[2] make a total of 96, and there seems to be little probability of this number being greatly increased.

LIST OF SPECIES NOW RECORDED FROM SIQUIJOR FOR THE FIRST TIME.

Excalfactoria lineata.
Calœnas nicobarica.
Actitis hypoleucos.
Bubulcus coromandus.
Falco ernesti.
Cacomantis merulinus.
Acanthopneuste borealis.
Motacilla melanope.
Anthus gustari.

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[1] *Proc. U. S. Nat. Mus.* Wash. (1898), **20**, 581.

[2] *Proc. U. S. Nat. Mus.* Wash. (1898), **20**, 564.

LIST OF SPECIES COLLECTED.[3]

PHASIANIDÆ.

Excalfactoria lineata (Scopoli).

One male and one female, both in adult plumage, were collected. Siquijor is a new locality for this species where it is known as *"bun-tóg."*

Gallus gallus (Linnæus).

One jungle cock was collected.

TRERONIDÆ.

Osmotreron vernans (Linnæus).

Two adult males of this handsome wood-dove. The eggs are pure white: two collected April 11, 1908, measure, 30 by 22.6 and 31.6 by 22.4. Two eggs collected at a somewhat later date measure, 27.5 by 21.2 and 27.3 by 21.2. The nest of this dove is a thin platform of coarse rootlets and tendrils with a few larger sticks as a foundation. Two or three dead leaves are scattered among the rootlets. The greatest diameter of the nest collected is about 200 millimeters and the greatest outside depth less than 30 mm.

Osmotreron axillaris (Bonaparte).

Four specimens in fine plumage have the wings slightly longer than do specimens from more northern islands, but the colors are not different. An egg taken from the oviduct of a female on April 15, 1908, measured 30 by 23.7.

Phapitreron albifrons McGregor.

Two specimens of the genus *Phapitreron* can not be distinguished from *P. albifrons* of Bohol.

Muscadivores chalybura (Bonaparte).

One male and one female of the imperial fruit pigeon are of this common variety of *M. ænea.*

Myristicivora bicolor (Scopoli).

One specimen of the nutmeg pigeon.

PERISTERIDÆ.

Streptopelia dussumieri (Temminck).

Two specimens of this common turtle dove.

Chalcophaps indica (Linnæus).

One specimen.

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[3] The metric system is used in all measurements here recorded. The vernacular names given under various species were found in use among the residents of the island and were collected by Mr. Celestino.

Calœnas nicobarica (Linnæus).

One female specimen and two live examples of the handsome Nicobar pigeon were secured in Siquijor, a new locality for this widely distributed species.

RALLIDÆ.

Hypotænidia torquata (Linnæus).

One female in fine, adult plumage; the local name is *"tic-ling."*

Amaurornis phœnicura (Forster).

One full-plumaged male and one slightly immature male; in the latter the breast is somewhat mottled with slaty gray. Name in Siquijor, *"qui-yaó."*

LARIDÆ.

Sterna boreotis (Bangs).

One male was taken on September 7, 1907.

CHARADRIIDÆ.

Squatarola squatarola (Linnæus).

A male in intermediate plumage was taken September 6, 1907.

Charadrius fulvus (Gmelin).

A male in intermediate plumage was taken September 6, 1907.

Actitis hypoleucos (Linnæus).

A female was collected in September, 1907. Siquijor is thus added to the long list of islands from which this common sandpiper is known.

ARDEIDÆ.

Nycticorax manillensis Vigors.

A fragment, consisting of head and neck, is identified as belonging to the Philippine night-heron.

Bubulcus coromandus (Boddaert).

A male of the cattle egret in breeding plumage. This species is called *"ta-la-bóng"* in Siquijor. Not previously noted from that island.

ANATIDÆ.

Dendrocygna arcuata (Horsfield).

A male of this common tree-duck.

FALCONIDÆ.

Haliastur intermedius Gurney.

This common buzzard is represented by the tail of an immature individual. It is known in Siquijor as *"ba-nóg."*

Falco ernesti Sharpe.

A fine male falcon is identified as being of this rare species. Although in somewhat immature plumage, a number of feathers on flanks and thighs, particularly on the latter, show the characteristic smoky gray color and the close-set, black bands. The measurements of this specimen follow: Wing, 300 millimeters; tail, 160; bill from front of cere, 21; tarsus, 45. The name of this species in Siquijor is *"a-na--nang-quil."*

BUBONIDÆ.

Ninox philippensis Bonaparte.

The single male obtained in Siquijor does not differ from specimens taken in Luzon.

CACATUIDÆ.

Cacatua hæmaturopygia (P. L. S. Müller).

Two males of the common Philippine cockatoo.

PSITTACIDÆ.

Tanygnathus lucionensis (Linnæus).

Two males collected.

Loriculus siquijorensis Steere.

This distinct species is similar to *L. mindorensis* but the red patch on the forehead ends in a point instead of ending squarely and the red patch on the breast covers about one-half the area that it does in *L. mindorensis*. The native name is *"co-lan-sí."*

ALCEDINIDÆ.

Alcedo bengalensis Brisson.

One specimen.

Halcyon gularis (Kuhl).

One male specimen of this common kingfisher; it has two names in Siquijor, *"uak-bá-ta"* and *"ma-nák-sak."*

Halcyon chloris (Boddaert).

One slightly immature female.

MEROPIDÆ.

Merops philippinus Linnæus.

Two specimens.

CYPSELIDÆ.

Collocalia troglodytes Gray.

One male specimen; known as *"sai-áo."*

CUCULIDÆ.

Cacomantis merulinus (Scopoli).

This common cuckoo is called *"yoi-hó"* in Siquijor; this is the first record of its occurrence in that island.

Eudynamis mindanensis (Linnæus).

The male collected shows no peculiarities. The local name is *"cu-la-haó."*

Centropus viridis (Scopoli).

The local name is *"cuk-cuk."* The fresh eggs, taken on April 7, 1908, measure 30.6 by 25.6 and 31.1 by 25.7. They are pure white. The nest was composed of sticks and had a small entrance in one side, the entire top being covered. The nest was built in a small bush at the height of a man's head.

PITTIDÆ.

Pitta atricapilla Lesson.

Two specimens were obtained of this widely distributed ant-thrush. Its local name is *"uao-há."*

HIRUNDINIDÆ.

Hirundo javanica Sparrmann.

One specimen.

MUSCICAPIDÆ.

Hemichelidon griseisticta (Swinhoe).

One male specimen.

Cyornis philippinensis Sharpe.

One specimen; this species is known as *"ca-man-ti-gon."*

Hypothymis occipitalis (Vigors).

One female.

Rhipidura nigritorquis Vigors.

This common flycatcher is called *"ba-li-á-la"* in Siquijor.

CAMPOPHAGIDÆ.

Lalage niger (Forster).

Name in Siquijor *"bu-ga-ung-ón."*

PYCNONOTIDÆ.

Iole siquijorensis Steere.

This interesting species appears to be fairly abundant in Siquijor where it is known as *"tig-ba-ya."* Its nearest relatives are *I. monticola* of Cebu and *I. cinereiceps* of Tablas. It differs from either of these species in having the top of head seal-brown without ashy gray tips to the feathers.

TURDIDÆ.

Petrophila manilla Boddaert.

One female specimen; known as *"yú-ta yú-ta."*

Copsychus mindanensis (Gmelin).

One male specimen; called *"a-ni-ní-hol."*

Pratincola caprata (Linnæus).

One female.

SYLVIIDÆ.

Cisticola exilis (Vigors and Horsfield).

This common grass warbler is called *"pi-rót"* in Siquijor.

Acanthopneuste borealis (Blasius).

This migratory warbler seems to have been unnoticed by previous collectors; two specimens were taken by Celestino.

ARTAMIDÆ.

Artamus leucorynchus (Linnæus).

One specimen.

LANIIDÆ.

Cephalophoneus nasutus (Scopoli).

Three specimens in good plumage.

Otomela lucionensis (Linnæus).

One specimen in immature plumage. The name *"ti-ba-lás"* is used for both *Otomela* and *Cephalophoneus*.

Hyloterpe apoensis Mearns.

A male from Siquijor agrees with numerous specimens of *Hyloterpe* from Bohol and these are best identified with *H. apoensis*, at the same time it may be noted that the single male of typical *apoensis* before me has a slightly smaller bill than any of the Bohol specimens or the single male from Siquijor.

ZOSTEROPIDÆ.

Zosterops siquijorensis Bourns and Worcester.

Numerous specimens; known as *"lu-lai-og"*. This bird is closely related to the species found in Basilan and Bohol but in the Siquijor species the sides of the breast are much lighter gray.

DICÆIDÆ.

Dicæum besti Steere.

A fair series was obtained of this near relative of *D. cinereigulare*. Local name *"pis-pis"*.

Dicæum pygmæum (Kittlitz).

One specimen of this plain flower-pecker.

NECTARINIIDÆ.

Cinnyris sperata (Linnæus).

Two adult males.

Cinnyris jugularis (Linnæus).

One female.

MOTACILLIDÆ.

Motacilla melanope Pallas.

Two females in rather poor plumage serve to add one more to the islands from which this species is known. Its name in Siquijor is *"a-na-nok-yód"*.

Anthus rufulus Vieillot.

Known in Siquijor as *"a-la-lak-síng"*.

Anthus gustavi Swinhoe.

One specimen; not previously known from Siquijor.

ORIOLIDÆ.

Oriolus chinensis Linnæus.

One specimen of this large oriole.

STURNIDÆ.

Sarcops melanonotus Grant.

The two bald starlings collected in Siquijor certainly approach this recently named race.

Lamprocorax panayensis (Scopoli).

Two specimens.

CORVIDÆ.

Corone philippina (Bonaparte).

The Philippine crow concludes the list of species from Siquijor.

SOME NECESSARY CHANGES IN THE NAMES OF PHILIPPINE BIRDS.

By RICHARD C. McGREGOR.

(From the Zoölogical Section, Biological Laboratory, Bureau of Science, Manila, P. I.)

Aluco longimembris (Jerdon).

Strix candida (not of Latham) TICKELL, Jour. As. Soc. Bengal (1833), **2**, 572.
Strix longimembris JERDON, Madras Journ. (1839), **10**, 86.

Dr. Charles W. Richmond writes me that the name usually applied to the grass owl is preoccupied by *Strix candida* Latham, Suppl. Ind. Orn. (1801), p. xiv which is a synonym for the snowy owl. The next available name is the one used by Jerdon.

The generic name *Strix* Linnæus is replaced by *Aluco* Flemng. *Cf.* Auk (1908), **25**, 370.

Megalurus tweeddalei new name.

Megalurus ruficeps (not of Sykes) TWEEDDALE, Ann. & Mag. Nat. Hist. (1877), **20**, 94; Proc. Zoöl. Soc. (1877), 695, pl. 72.

The name *Megalurus ? ruficeps* is used by Sykes for an Indian species in Proc. Zoöl. Soc. (1832), 91. As this invalidates the use of this name for the Philippine species, the latter, figured and described by Lord Tweeddale, may be known as *Megalurus tweeddalei.*

Zosterops boholensis new name.

Zosterops læta (not of De Vis) McGREGOR, Phil. Jour. Sci. (1907), **2**, Sec. A, 329.

The name under which the silver-eye of Bohol was described had been used before for a species from New Guinea, see *Zosterops læta* De Vis, Ibis (1897), 385. The Bohol species may therefore be named for the island which it inhabits.

Cinnyris henkei Meyer.

Cinnyris henkei MEYER, Zeitschr. für Ges. Orn. (1884), 207, pl. 7.
Cinnyris whiteheadi GRANT, Bull. Brit. Orn. Club (1894), **2**, 1; Ibis (1894), 514, pl. 14, fig. 1.

The black-backed sun-bird, described and figured by Grant as *Cinnyris whiteheadi,* finds an earlier name in *Cinnyris henkei* as indicated by Dubois, Syn. Av. (1902), 699.

PHILIPPINE ORNITHOLOGICAL LITERATURE, I.

By Richard C. McGregor.

(From the Zoölogical Division, Biological Laboratory, Bureau of Science, Manila, P. I.)

This is the first of a series of papers having for its final object a complete bibliography of Philippine ornithology. Primarily, however, these papers are intended to indicate exactly what works are available in Manila and to explain the bearing of each paper or volume on the study of Philippine birds. Particular effort will be made to record, promptly, recent and current publications which deal specifically with the Philippine ornis, but older works and those of a more general character will be included. Each installment of Philippine ornithological literature will consist of about fifty titles and will be issued from time to time as material becomes available.

Gadow, H.: Paridæ and Laniidæ (titmice and shrikes), and Certhiomorphæ (creepers and nuthatches). Cat. Birds Brit. Mus. London (1883), **8**, 1–386, pls. 1–9.

This essential volume contains synonymy, keys, and descriptions of all species of titmice, shrikes, and nuthatches known at date of publication. No Philippine species is figured.

Gadow, H.: Nectariniidæ. Cat. Birds Brit. Mus. London (1884), **9**, 1–126, pl. 1.

This essential volume contains synonymy and descriptions of all species of sun-birds known at the date of publication. No Philippine species is figured.

Grant, W. R. O.: Steganopodes (cormorants, gannets, frigate-birds, tropic-birds, and pelicans). Pygopodes (divers and grebes). Cat. Birds Brit. Mus. London (1898), **26**, 329–558, pls. 5a–8.

This includes synonymy, keys, and descriptions of all Philippine species in the Steganopodes and Pygopodes known at date of publication. No Philippine species is figured. This work is essential.

Grant, W. R. O.: Bucerotes and Trogones. Cat. Birds Brit. Mus. London (1892), **17**, 347–497, pls. 13–17.

Synonymy, keys, and descriptions of all the known trogons and hornbills. No plates of Philippine species. *Gymnolæmus*, new genus for *Anthracoceros lemprieri* Sharpe. This work is essential.

Grant, W. R. O.: Game birds (Pterocletes, Gallinæ, Opisthocomi, Hemipodii. Cat. Birds Brit. Mus. London (1893), **22**, 1–588, pls. 1–8.

Descriptions and synonymy of all Philippine species of *Megapodiidæ*, *Phasianidæ*, and *Turnicidæ* are included, but no plates of Philippine species.

Grant, W. R. O.: On the birds of the Philippine Islands.—Part I. Mount Arayat, Central Luzon. *Ibis* (1894), 406–411.

This is the first of the series of important papers by Grant on the collections made by John Whitehead; 40 species are listed.

Grant, W. R. O.: On the birds of the Philippine Islands.—Part II. The highlands of north Luzon, 5,000 feet. *Ibis* (1894), 501–522, pls. 14 and 15.

This is an important paper on a collection of 94 species from (vicinity of Trinidad?), Benguet Province. Two new species, *Muscicapula luzoniensis* and *Cittia seebohmi*, are described and the following 17 species, first characterized in Bull. Brit. Orn. Club, are more fully described: *Scops longicornis*, *Oriolus albiloris*, *Stoparola nigrimentalis*, *Merula thomassoni* Seebohm, *Chimarrhornis bicolor*, *Zosterornis whiteheadi*, *Hyloterpe albiventris*, *Lanius validirostris*, *Dendrophila mesoleuca*, *Æthopyga flavipectus*, *Eudrepanis jefferyi*, *Cinnyris whiteheadi*, *Cinnyris obscurior*, *Dicæum luzoniense*, *Dicaæum obscurum*, *Loxia luzoniensis*, and *Chlorura brunneiventris*. Two species, *Emberiza pusilla* and *E. sulfurata*, are recorded as new to the Philippine avifauna. *Cinnyris whiteheadi*, *Stoparola nigrimentalis*, *Zosterornis whiteheadi*, and *Chimarrhornis bicolor* are figured on the two plates.

Grant, W. R. O.: On the birds of the Philippine Islands.—Part III. The mountains of the Province of Isabela, in the extreme northeast of Luzon. *Ibis* (1895), 106–117, pls. 4 and 5.

This important paper lists 30 species from Isabela Province and contains additional notes on *Oriolus isabellæ* and *O. albiloris*, which were previously described in Bull. Brit. Orn. Club. *Zosterornis striatus* is described as new; *Munia formosana* and *Cotile sinensis* are added to the Philippine list. *Zosterornis striatus*, *Dendrophila mesoleuca*, *Æthopyga flavipectus*, and *Eudrepanis jefferyi* are the subjects of the two plates.

Grant, W. R. O.: On the birds of the Philippine Islands.—Part IV. The Province of Albay, southeast Luzon, and the adjacent Island of Catanduanes. *Ibis* (1895), 249–267.

This paper lists 46 (?) species from Albay Province and 48 species from Catanduanes. Additional descriptions and notes are given of *Callaeops periopthalmica*, *Zosterops luzonica*, and *Cinnyris excellens* which were previously described in Bull. Brit. Orn. Club. There are extended notes on variation in *Sarcops calvus* and *Prioniturus discurus*. *Carpophaga poliocephala* is recorded from Luzon for the first time and *Emberiza spodocephala* from Catanduanes is recorded as new to the Philippines.

Grant, W. R. O.: On the birds of the Philippine Islands.—Part V. The highlands of the Province of Lepanto, north Luzon. *Ibis* (1895), 433–472, pls. 12–14.

Notes on 110 species. Additional descriptions of *Scops longicornis*, *Scops whiteheadi*, *Rhinomyias insignis*, *Lusciniola seebohmi*, *Cettia seebohmi*, *Brachypteryx poliogyna*, *Pseudotharrhaleus caudatus*, *Zosterops aureiloris*, *Pyrrhula leucogenis*, *Batrachostomus microrhynchus*, and *Prioniturus monta-*

nus, which were previously described in Bull. Brit. Orn. Club. *Collocalia whiteheadi* is described as new; *Cinnyris obscurior* is rejected as being based on *C. jugularis* in worn plumage; *Pitta kochi* and *Ptilopus marchei* and the females of *Dicæum xanthopygium* and *Cittocincla luzoniensis* are fully described. Notes on plumages of *Macropygia tenuirostris; Falco severus* added to the Luzon list; *Cerchneis tinnunculus* and *Collocalia linchi* added to the Philippine list.

Grant, W. R. O.: On the birds of the Philippine Islands.—Part VI. The vicinity of Cape Engaño, northeast Luzon, Manila Bay, and Fuga Island, Babuyan Group. *Ibis,* (1896), 101–128, pl. 3.

Additional notes and descriptions of *Siphia enganensis, Hypsipetes fugensis, Orthotomus chloronotus,* and *Zosterornis dennistouni* all previously described in Bull. Brit. Orn. Club. Critical notes on the plumages of *Accipiter gularis.* Young male of *Parus semilarvatus* described. First Luzon record of *Fregata minor.* Notes on the *Eudynanis* of Fuga. *Orthotomus chloronotus* and *Zosterornis dennistouni* are figured on the plate.

Grant, W. R. O.: On the birds of the Philippine Islands.—Part VII. The highlands of Mindoro. *Ibis* (1896), 457–477, pl. 11.

A list of 52 species with numerous notes. *Ninox mindorensis* and *Turdus mindorensis,* new species. *Carpophaga mindorensis* Whitehead, is redescribed and figured. *Locustella ochotensis* is recorded, for the second time, from the Philippines. Notes on *Scops* sp. inc., later described by Whitehead as *S. mindorensis.* A useful key to the Philippine species of *Iyngipicus* is given.

Grant, W. R. O.: On the birds of the Philippine Islands.—Part VIII. The highlands of Negros. *Ibis* (1896), 525–565.

A list of 86 species; *Artamides cebuensis, Turdus nigrorum, Brachypteryx brunneiceps,* and *Cittocincla nigrorum,* new species. Keys to the Philippine species of *Oriolus, Rhinomyias, Artamides,* and *Edoliisoma. Oriolus basilanicus,* new name. First Negros records for *Tanygnathus everetti* and *Surniculus velutinus;* first Philippine record for *Cuculus micropterus. Iole guimarasensis* is considered to be distinct from *Iole philippensis; Munia brunneiceps* is considered to be the worn plumage of *M. jagori.* Notes on the plumages of *Spilornis panayensis* and *Falco ernesti.*

Grant, W. R. O.: On the birds of the Philippine Islands.—Part IX. The Islands of Samar and Leyte. *Ibis* (1897), 209–250, pls. 5 and 6.

A list of 93 species with numerous notes. Additional notes on *Pithecophaga jefferyi, Rhabdornis minor,* and *Rhabdornis inornatus,* which were previously described in Bull. Brit. Orn. Club. *Microhierax meridionalis* is described as new; notes on *Ceyx;* female of *Microstictus fuliginosus* described. Keys to the Philippine species of *Orthotomus, Macronus, Zosterornis,* and *Rhabdornis. Poliolophus basilanicus* is considered not distinct from *P. urostictus.* Eight species new to Samar and 14 species new to Leyte.

Grant, W. R. O.: On the birds collected by Mr. Walter Goodfellow on the volcano of Apo and in its vicinity, in southeast Mindanao, Philippine Islands. *Ibis* (1906), 465–505, pls. 18 and 19.

A list of 124 species with many critical and field notes. *Hypocryptadius cinnamomeus, Rhinomyias goodfellowi,* and *Pericrocotus johnstoniæ* are figured. This paper lists no new species but contains redescriptions of many species previously described in Bull. Brit. Orn. Club. *Geocichla andromeda* recorded as new to the Philippines. Four species, *Caprimulgus griseatus*, *Turdus obscurus*, *Anthus maculatus*, and *Anthus gustavi*, are noted as new to Mindanao.

Grant, W. R. O., and **Whitehead, J.**: On the nests and eggs of some rare Philippine birds. *Ibis* (1898), 231–247, pls. 5 and 6.

Short descriptions and measurements of the eggs of 36 species, mostly from specimens collected by Whitehead. The two plates illustrate the eggs of sixteen species.

Hargitt, E.: Scansores, containing the family Picidæ. Cat. Birds Brit. Mus. London (1890), **18**, 1–598, pls. 1–15.

Synonymy, keys, and descriptions of all the woodpeckers known at date of publication. The Philippine species figured are *Chrysocolaptes rufopunctatus* and *Thriponax pectoralis*. This book is essential.

Hartert, E.: Cypselidæ, Caprimulgidæ, and Podargidæ. Cat. Birds Brit. Mus. London (1892), **16**, 434–652, pls. 10–14.

Synonymy, keys, and descriptions of all swifts, night-jars, and frogmouths known at date of publication. Plates of *Caprimulgus griseatus* and *Lyncornis mindanensis*. Essential for a study of these families.

Hartert, E.: Die bisher bekannten Vögel von Mindoro, nebst Bemerkungen über einige Vögel von anderen Inseln der Philippinen-Gruppe. *Jour. für Orn.* (1891), 87–206, 292–302.

Notes on 68 species, mostly from Mindoro. The introduction contains a short account of the work done by Philippine collectors.

Kutter, F.: Beitrag zur Ornis der Philippinen. *Jour. für Orn.* (1883), 1–28 of reprint.

An annotated list of 54 species collected by Koch and Schadenberg at Sibulan, southern Mindanao. *Graucalus kochii* is the only new species. *Yungipicus maculatus* is added to the Guimaras list; *Collocalia linchi*, *Lanius nasutus*, *Hypothymis superciliaris*, *Zeocephus rufus*, *Dendrophila urochlamys*, *Oxycerca everetti*, and *Excalfactoria chinensis* are recorded for the first time from Mindanao.

Salvadori, T.: Catalogue of the Columbæ, or pigeons, in the collection of the British Museum. Cat. Birds Brit. Mus. London (1893), **21**, 1–676, pls. 1–15.

Contains synonymy, keys, and descriptions of all doves and pigeons known at date of publication. *Osmotreron axillaris* is the only Philippine species figured. *Phabotreron occipitalis* is described as new. This volume is necessary for a study of the Columbæ.

Salvadori, T.: Catalogue of the Psittaci, or parrots, in the collection of the British Museum. Cat. Birds Brit. Mus. London (1891), **20**, 1–660, pls. 1–18.

Contains synonymy, keys, and descriptions of all the known parrots. The Philippine species figured are: *Tanygnathus everetti*, *Tanygnathus burbidgei*, and *Bolbopsittacus intermedius*, the last a new species. *Bolbopsittacus* is a new genus with *Psittacus lunulatus* Scopoli as the type. This volume is quite essential for the study of the parrots.

Salvadori, T.: Anseres. Cat. Birds Brit. Mus. London (1895), **27,** 23–93, pls. 1–5.

An important review of the ducks, geese, and swans with keys, synonymy, and descriptions. *Dendrocygna guttulata* is the subject of Plate I.

Salvadori, T.: On a rare species of lorikeet in the Rothschild collection. *Ibis* (1891), 48–51, pl. 3.

Description and plate of *Loriculus bonapartei*.

Salvadori, T.: On *Melaniparus semilarvatus*. *Ibis* (1879), 300–309, pl. 9.

Plate and notes on this species.

Salvin, O.: Tubinares (petrels and albatrosses). Cat. Birds Brit. Mus. London (1896), **25,** 340–455, pls. 1–8.

A review of this order with keys, synonymy, and descriptions. The only Philippine species is described on page 370.

Saunders, H.: Gavidæ (terns, gulls, and skuas). Cat. Birds Brit. Mus. London (1896), **25,** 1–339.

Synonymy, keys, and descriptions of all known species of gulls and terns. No Philippine species is figured.

Sclater, P. L.: Pittidæ and Eurylæmidæ. Cat. Birds Brit. Mus. London (1888), **14,** 411–449; 454–470.

Synonymy, keys, and descriptions of all the pittas and rollers known at date of publication. No species from either of these families is figured. This is an important work.

Seebohm, H.: Catalogue of the Passeriformes, or perching birds, in the collection of the British Museum. Cichlomorphæ: Part II containing the family Turdidæ (warblers and thrushes). Cat. Birds Brit. Mus. London (1881), **5,** 1–426, pls. 1–18.

Synonymy, keys, and description of all species known in this group at the date of publication. *Locustella fasciolata* is the only Philippine species among the plates.

Sharpe, R. B.: Catalogue of the Accipitres, or diurnal birds of prey, in the collection of the British Museum. Cat. Birds Brit. Mus. London (1874), **1,** 1–480, pls. 1–14.

Synonymy and descriptions with keys of all species of eagles, hawks, etc., known at time of publication. The Philippine species figured are: *Astur soloensis*, *Astur cuculoides*, and *Baza magnirostris*. A necessary volume.

Sharpe, R. B.: Catalogue of the Striges, or nocturnal birds of prey, in the collection of the British Museum. Cat. Birds Brit. Mus. London (1875), **2,** 1–326, pls. 1–14.

Synonymy and descriptions with keys of all species of owls known at date of publication. No Philippine species is figured. A necessary volume.

Sharpe, R. B.: Professor Steere's expedition to the Philippines. *Nature* (1876), **14**, 297, 298.

A short account of Steere's first expedition to the Philippines and brief preliminary descriptions of ten new species: ***Eurylæmus steerii, Phyllornis palawanensis, Brachyurus steerii, Æthopyga magnifica, Æthopyga shelleyi, Æthopyga pulcherrima, Arachnothera dilutior, Dicæum dorsale, Dicæum hypoleucum,*** and ***Dicæum hæmatostictum.***

Sharpe, R. B.: Catalogue of the Passeriformes, or perching birds, in the collection of the British Museum. Coliomorphæ containing the families Corvidæ, Paradiseidæ, Oriolidæ, Dicruridæ, and Prionopidæ. Cat. Birds Brit. Mus. London (1877), **3**, 1–344, pls. 1–14.

Synonymy, keys, and descriptions of all species of the families named in the title. ***Oriolus steerii*** new species is the only Philippine species figured. An important work.

Sharpe, R. B.: Catalogue of the Passeriformes, or perching birds, in the collection of the British Museum. Cichlomorphæ: part I containing the families Campophagidæ and Muscicapidæ. Cat. Birds Brit. Mus. London (1879), **4**, 1–494, pls. 1–14.

Contains keys, synonymy, and descriptions of the species in the families named. The work is important. No Philippine species is figured.

Sharpe, R. B.: A contribution to the avifauna of the Sooloo Islands. *Proc. Zoöl. Soc.* London (1879), 311–317.

Notes on 20 species mostly collected by Burbidge in the Island of Sulu. The new species described are ***Tanygnathus burbidgii*** and ***Gallus stramineicollis.***

Sharpe, R. B.: A list of the birds of Labuan Island and its dependencies. *Proc. Zoöl. Soc.* London (1879), 317–354, pl. 30.

A list of 137 species largely from the collections of Low, Ussher, and Treacher, with valuable notes. The paper includes interesting references to a number of species which range to the Philippines.

Sharpe, R. B.: Catalogue of the Passeriformes, or perching birds, in the collection of the British Museum. Cichlomorphæ: part III containing the first portion of the family Timeliidæ (babbling-thrushes). Cat. Birds Brit. Mus. London (1881), **6**, 1–422, pls. 1–18.

An important work on the first part of the ***Timeliidæ*** with keys, descriptions, and synonymy. The Philippine species figured are: ***Iole rufigularis, Criniger frater,*** and ***Criniger palawanensis.***

Sharpe, R. B.: Catalogue of the Passeriformes, or perching birds, in the collection of the British Museum. Cichlomorphæ: part IV containing the concluding portion of the family Timeliidæ (babbling-thrushes). Cat. Birds Brit. Mus. London (1883), **7**, 1–700, pls. 1–15.

An important work on part of the family *Timeliidæ* with keys, synonymy, and descriptions; no Philippine species figured.

Sharpe, R. B.: Description of a new species of hornbill from the Island of Palawan. *Proc. Zoöl. Soc.* London (1885), 446, pl. 26.

Description and plate of *Anthracoceros lemprieri.*

Sharpe, R. B.: Catalogue of the Passeriformes, or perching birds, in the collection of the British Museum. Fringilliformes: part I containing the families Dicæidæ, Hirundinidæ, Ampelidæ, Mniotiltidæ, and Motacillidæ. Cat. Birds Brit. Mus. London (1885), **10**, 1–682, pls. 1–12.

Synonymy, keys, and descriptions of all the flower-peckers, swallows, and wag-tails known at date of publication. Philippine species figured are *Motacilla ocularis* and *Motacilla flava.* A very important volume.

Sharpe, R. B.: Notes on a collection of birds made by Mr. John Whitehead on the mountain of Kina Balu, in northern Borneo, with descriptions of new species. *Ibis* (1887), 435–454, pls. 13 and 14.

Cryptolopha montis new species, described.

Sharpe, R. B.: On a collection of birds from the Island of Palawan. *Ibis* (1888), 193–204, pls. 3 and 4.

A list of 129 species collected by Whitehead. Eight new species are described: *Prioniturus cyaneiceps, Baza leucopias, Syrnium whiteheadi, Scops fuliginosa, Hyloterpe whiteheadi, Siphia erythacus, Iole striaticeps,* and *Prionochilus johannæ.* Three of the new species are figured: *Syrnium whiteheadi, Siphia erythacus,* and *Prionochilus johannæ.*

Sharpe, R. B.: Catalogue of the Passeriformes, or perching birds, in the collection of the British Museum. Fringilliformes: part III, containing the family Fringillidæ. Cat. Birds Brit. Mus. London 1888), **12**, 1–872, pls. 1–16.

Synonymy, keys, and descriptions of all the *Fringillidæ* known at date of publication. No Philippine species is figured.

Sharpe, R. B.: On the ornithology of northern Borneo. With notes by John Whitehead. *Ibis* (1889–1890.) Seven parts with pages and plates as follows: Part I, (1889), 64–85, pls. 2–4; part II, (1889), 185–205, pls. 7 and 8; part III (1889), 265–283, pl. 9; part IV (1889), 409–443, pls. 11 and 13; part V (1890), 1–24; part VI (1890), 133–149, pl. 4; part VII (1890), 273–292, pl. 8.

This important contribution to the ornithology of Borneo contains numerous notes on species which range to the Philippines. *Cryptolopha montis* is figured in part II, pl. 8. Part VII, pp. 274–285, contains a table of distribution showing the relation of the Bornean ornis to that of the surrounding islands.

Sharpe, R. B.: Catalogue of the Passeriformes, or perching birds, in the collection of the British Museum. Sturniformes, containing the families Artamidæ, Sturnidæ, Ploceidæ, Alaudidæ, also the families Atrichiidæ and Menuridæ. Cat. Birds Brit. Mus. London (1890), **13**, 1–702, pls. 1–15.

Synonymy, keys, and descriptions of the swallow-shrikes, starlings, weaver-finches, and larks known at date of publication. No Philippine species is figured. *Spodiopsar* new name, page 665, to replace *Poliopsar* Sharpe, preoccupied. *Munia cabanisi* new name, page 353.

Sharpe, R. B.: Coraciidæ, Meropidæ, Alcedinidæ. Cat. Birds Brit. Mus. London (1892), **17**, 4–312 pls. 1–12.

A review of the rollers, bee-birds, and kingfishers with keys, synonymy, and descriptions. *Ceyx steerii* is described as new. The Philippine species figured are *Eurystomus orientalis* and *Halcyon chloris*. This is a very important work.

Sharpe, R. B.: Rallidæ and Gruidæ. Cat. Birds Brit. Mus. London (1894), **23**, 1–228; 248–277, pls. 1–9.

The rails and cranes are described with keys and full synonymy. The work is an important one. *Rallina euryzonoides* is the subject of figure 1 on plate 8.

Sharpe, R. B.: Catalogue of the Limicolæ in the collection of the British Museum. Cat. Birds Brit. Mus. London (1896), **24**, 1–796, pls. 1–7.

A very important review with descriptions, keys, and synonymy of all the Limicolæ. No plates of Philippine species.

Sharpe, R. B.: Plataleæ (ibises and spoonbills) and Heroniones (herons and storks). Cat. Birds Brit. Mus. London (1898), **26**, 1–328, pls. 1–5.

An important review of these birds with descriptions, keys, and synonymy. The Philippine species figured are *Phoyx manillensis* and *Butorides spodiogaster*.

Shelley, G. E.: Capitonidæ and Cuculidæ. Cat. Birds Brit. Mus. London (1891), **19**, 13–121; 209–434, pls. 1–5; 11–13.

The parts of this volume indicated above, dealing with the barbets and cuckoos, include keys, synonymy, and descriptions of all species known at the date of issue. A useful and necessary work; no Philippine species is figured.

AN IMPROVED METHOD OF MODELING ESPECIALLY ADAPTED FOR THE CENTRAL NERVOUS SYSTEM.

(*From the Anatomical Laboratory, Philippine Medical School, Manila, P. I.*)

PREPARATION OF BRAIN MODELS.

By MARIA PAZ MENDOZA AND MANUEL RAMIREZ.

During the last summer session of the Philippine Medical School, Dr. Bean recommended to us the study of the nervous system and suggested that in the dissection of the brain we make at least three different sections, sagittal, coronal (frontal), and horizontal, and take an exact copy of the two surfaces of each section on pieces of blotting paper,[1] cut out the ventricles and paste each two, which complete one section, together by means of small cubes of wood cut in such a way that the resulting thickness is just the same as that of the original section. The idea was to show the shape, size and relative position of the brain ventricles through the gaps left by the pieces of blotting paper pasted on the blocks, and on the blotting paper to show the internal structure of the brain. We adopted the suggestion and thought it capable of further improvement by substituting for the blocks of wood blotting-paper pulp, thus also gaining the external morphology and converting the work into true modeling. We found this to be an easy, economic, interesting and accurate work, the success of which is shown by the photographs accompanying this description.

PROCESS.

1. ***Materials:*** Blotting paper, white and onion skin paper, gum arabic and paints.

2. *Procedure:* Preparation of sections.

For coronal sections, an entire brain was taken from the preserving fluid,[2] held on a mass of cotton and ten sections of equal thickness made with a brain knife.

Sagittal and horizontal sections.—The brain is first divided into halves, by making a cut through the longitudinal fissure, separating the brain-stem at the middle. One-half of the brain is then cut into four sagittal sections of the same thickness; the other half into four horizontal sections of the same depths. Thinner sections may be made, yet they are not desirable for beginners.

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[1] **Sussana Phelps Gage: The Method of Making Models from Sheets of Blotting Paper. *The Anatomical Record.* (1907), 7, 166.**

[2] **Müller's fluid was employed** so that the same material could be used for work **on the histology of the brain.**

Making the pulp.—Waste blotting paper that has been used is pulled apart by hand[3] into small pieces and put into water to macerate, care being taken first to wash the mass two or three times. When the pieces become soft they are reduced to a fine pulp with the fingers. The surplus water is then squeezed out and the pulp thoroughly mixed with gum which has previously been dissolved.

Making copies of the contiguous surfaces of two adjacent sections.—The most anterior coronal section is first taken, held on a mass of cotton, the cut surface to be copied is then moistened with the preserving fluid and the onion skin paper immediately placed upon it. The structures beneath the latter are now plainly visible and their outlines can be followed with a sharp pencil, thus making an exact copy of the posterior surface of this section of the brain and the anterior surface of the next. When this part of the work is finished, two pieces of white paper with two of blotting paper are taken, the onion skin paper placed over them and the external outline of the section cut through them. The blotting paper is then set aside and two pieces of carbon paper inserted between the pieces of white paper in such a manner that when redrawn, the outline of the section on the onion skin paper gives two copies on the white, representing the two adjacent surfaces, one of this and one of the next section. By proceeding in the same manner with the remainder of the sections copies of their surfaces can be obtained.

Model preparation.—The work is now ready for modeling.

The two pieces of blotting paper, set aside in the last preparation, which correspond to the anterior and posterior surfaces, for example of coronal section number 2, are taken, the surfaces to be put in contact with the pulp are painted with thick gum and between them such a quantity of pulp, previously squeezed of its surplus liquid, is placed so that its thickness is about 1 millimeter, for every centimeter, more than the original section of the brain. The less the water and the more homogeneous the pulp, the less will be the shrinkage of the model in drying. The border is now made even throughout with fingers, forceps, and probes; once all the sections are thus made they are put together in their natural position and the rough outline of the most important and deep fissures such as those of Sylvius and Rolando and the longitudinal fissure are marked. Afterwards, taking each section individually, the sulci and gyri are worked out with the original section as a model, the two adjacent sections being occasionally consulted for their exact locations. Whenever the pulp dries too much it is moistened with a diluted solution of gum arabic.

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[3] Not cut with a scissors or knife.

Painting the model.—To distinguish the white from the gray matter and the different structures inside the brain from each other, water colors are used for all but the cortex, where oil is preferable. While the model is drying the two outlined pieces of white paper corresponding to section No. 2 are taken and with the original sections at hand the different parts are painted with different colors, giving the same color to those parts having the same or allied structure.

Last step.—When the model-sections are dried (which takes about one week, or longer, according to the water contained in the pulp), the white papers containing the copies of the surfaces of the sections are pasted on them and the gap left around the border, due to a slight contraction of the blotting paper, is filled up with pulp and left to dry. Next, the cavity for the ventricles is excised, as this can not be done when the pulp is moist, the newly exposed parts painted and after all is completed the outside is painted with oil colors. The same procedure is followed for the coronal sections and the sagittal and horizontal ones.

The record book.—A record book should be kept in which the onion skin papers containing the outlines of the internal structures should be preserved and to each of these the corresponding name should be given as their study is continued.

Experiments.—With the hope of further improving brain modeling we conducted some experiments the results of which are as follows:

Newspaper, macerated for three days in water, and reduced to a fine pulp of dark-gray color, has short fibers, but forms a soft mass easily workable into any desired shape. Painted with oil colors, almost no contraction occurs when drying and sections can easily be reduced to an 8 millimeter thickness.

With one-half newspaper pulp and one-half lime a pulp is produced that can be used to make sections 8 millimeters thick; this dries within twenty-four hours into a hard, strong, white mass with an even surface, which is easily painted. With gum the resulting mass is more plastic, but dries less quickly.

With one-third pulp, one-third lime and one-third sand, the mass is dark and dries more quickly, but it is brittle and not adapted for brain modeling.

We repeated the above experiments with magazine paper and ordinary white paper and obtained almost the same results.

This method of modeling can obviously be used for other purposes such as the reproduction of fruits, insects, etc., so that it can be made of advantage to botanists, zoölogists, paleontologists, etc.

PREPARATION OF BRAIN MODELS.

By Pio Valencia Enriquez.

The blotting-paper pulp is prepared as described in the work of Mendoza and Ramirez. The two hemispheres of a brain are then separated with a *sharp, thin-bladed knife,* and four vertical-longitudinal (sagittal) sections of one hemisphere made, the cuts being 1.5, 3, and 4.5 centimeters, respectively, from the mesial surface. The mesial section is then placed on the table and an exact outline of the structures found on each of its two surfaces drawn through transparent paper. Two pieces of blotting paper are cut from these outlines. A sufficient quantity of the macerated blotting paper is then put on the table, and compressed with a flat board until it becomes somewhat solid and nearly as thin as the mesial brain section. Its exposed surface is now ready for a coat of library paste which is first put on thin, then thick, and the proper blotting paper outline is then attached to this by compression. The other surface is treated in like manner and the remaining sections are made in the same way.

The exposed borders are then trimmed, the gyri, sulci, and ventricles being modeled while the material is soft and plastic, all exposed surfaces being coated with library paste.

Drying.—The models dry better in the shade than in the sunshine, rapid drying causing them to warp and to lose their shape. They should be placed in a closed locker over a pile of blotting papers on a plane surface. The model should be turned once or twice each 24 hours and the blotting papers should be replaced with dry ones at the same time, in order to facilitate the drying process. After the models are dry they may be painted in any way desired.

Caution.—All models made in this way must be preserved in closed cases, especially in the tropics, in order that rats, roaches, and other vermin may not mutilate or destroy them.

ILLUSTRATIONS.

PLATE I.

FIG. 1. Mesial surface of model of right hemisphere showing separation of sections. Mendoza and Ramirez.

2. Superior view of the first section from the base of the hemisphere. Mendoza and Ramirez.

3. Superior surface of the second section from the base of the hemisphere. Mendoza and Ramirez.

PLATE II.

FIG. 1. Coronal section number 5, showing the posterior surface. Mendoza and Ramirez.

2. Coronal section number 6, showing the posterior view. Mendoza and Ramirez.

3. Model of the right hemisphere of a human brain viewed from the side. Valencia.

PLATE III.

FIG. 1. Same as Plate II, fig. 3, with the first lateral section of the cerebral hemisphere removed. Represents a sagittal section 4.5 centimeters from the mesial surface. Valencia.

2. Same as Plate II, fig. 3, with the first and second sagittal sections removed. Represents a sagittal section 3 centimeters from the mesial surface. Valencia.

3. With the first, second, and third lateral sagittal sections removed. Represents a sagittal section 1.5 centimeters from the mesial surface. Valencia.

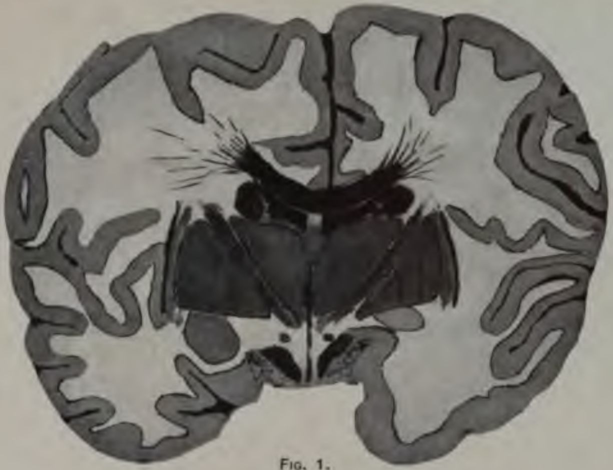

FIG. 1.

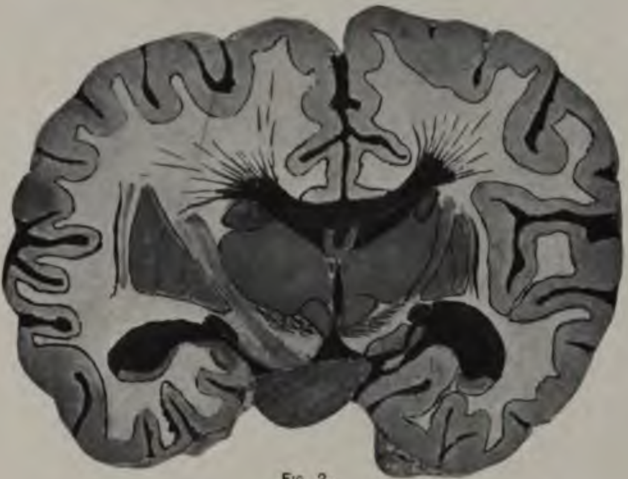

FIG. 2.

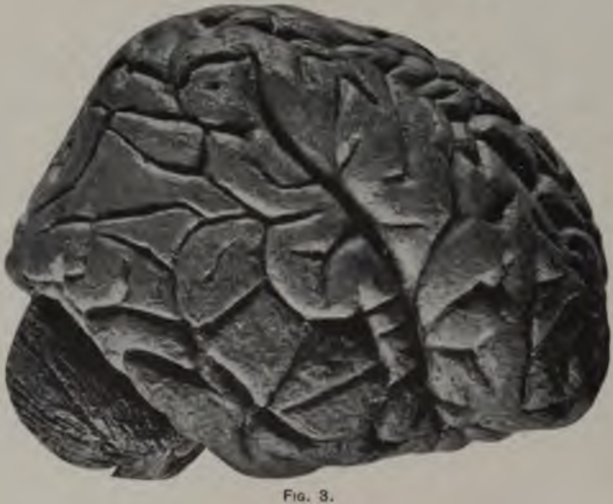

FIG. 3.

PLATE II.

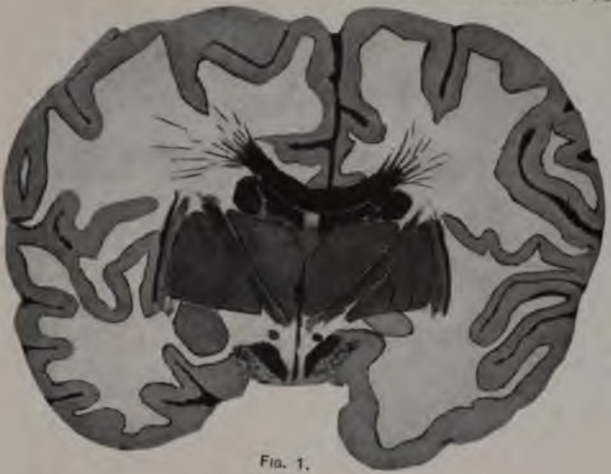

FIG. 1.

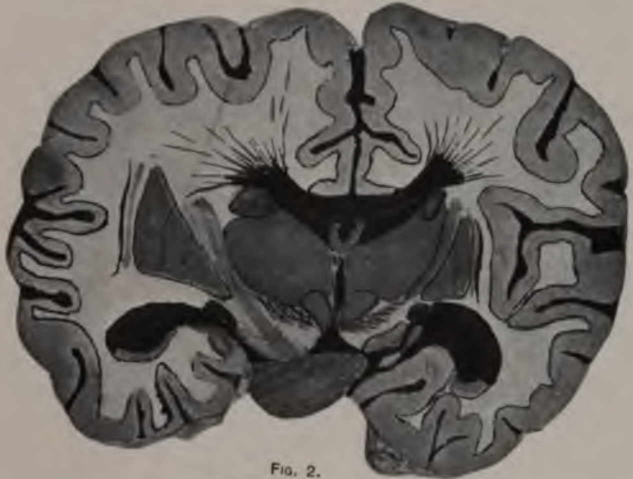

FIG. 2.

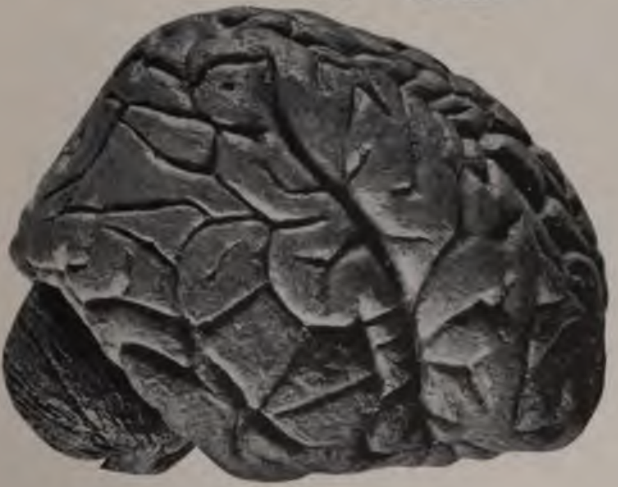

FIG. 3.

PLATE II.

EDITORIAL.

NOTES ON THE APPEARANCE OF SIREX JUVENCUS LINN. IN MANILA, P. I.

A few days ago a representative of a Manila importing house brought to this office an insect for determination which was found inside a packing case recently received from Germany. I have identified it as *Sirex juvencus* Linn.[1] This wood-wasp is common in Germany and is well known to foresters as injurious to *Pinus sylvestris* Linn.

The history of its introduction is as follows. A Filipino in opening a packing case noticed that about ten of the insects flew out, while at the bottom of the box several dead specimens were found. The packing case contained cotton underwear, packed in pasteboard boxes, and it was noticed that the insects had eaten holes in these inner boxes and had slightly injured their contents.

Unfortunately I did not see the packing case, but I have no doubt but that it was made of pine wood, in which the insects passed the last stages of their development. The wasps after hatching emerged on the inside of the box, and in attempting to escape attacked the contents of the box.

W. Schultze.

NOTES ON THE ABUNDANT APPEARANCE OF GIBBIUM SCOTIAS FABR. IN THE PHILIPPINE ISLANDS.

Some time ago Mr. Herbert S. Walker, chemist of this Bureau, called my attention to the fact that there were numerous beetles present in a material known as argol.[2] Upon investigation I found enormous numbers of a beetle which I have identified as *Gibbium scotias* Fabr., together with some specimens of *Tribolium ferrugineum* Fabr. The

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[1] In German, "Die gemeine Kiefernholzwespe," see Ratzeburg, *Forst-Insecten* (1844), 3, 143, taf. IV, fig. 3.

[2] Argol (German, Weinstein) is a crude cream of tartar or potassium acid tartrate which forms as a crust on the inside of vessels in which wine has been fermented. The color is purple to white, according to the kind of wine. It is used as a reducing agent in gold and silver assays. The purified cream of tartar is used in medicine and to a large extent in the manufacture of baking powders. Our supply came in 50-kilogram barrels from a firm in New York.

50-kilogram barrel of argol was nearly full and throughout the mass it was infested with larvæ and cocoons of the first-mentioned species. As the barrel had been open for some time there was a possibility that the beetles might have entered it after it had reached Manila. I therefore examined a fresh barrel of argol which was kept in another part of the building. The outside of this package was in perfect condition and showed no signs of holes, but its contents were infested throughout. The surface of the argol was covered with a shiny mass of dead and living beetles of *G. scotias* Fabr. The above-mentioned facts convinced me that this species was introduced or imported with the argol from the United States. This species probably found suitable climatic conditions and multiplied rapidly. In the literature which I have consulted I find no mention of this species having been detected in argol, although it seems to have a somewhat peculiar sense of taste. Some authors mention it as feeding on the dust of granaries;[3] Laboulbène[4] found it on an Egyptian mummy in large numbers; Lucas[5] saw larvæ and adults feeding on red pepper (*Capsicum annuum* Linn.), and Stierlin[6] on the wool of sheep.

Should this beetle at any time adapt itself to food of more economic value and importance than the variety mentioned, serious damage might arise.

W. SCHULTZE.

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[3] Boieldieu, "Monographie des Ptiniores," *Ann. Soc. Ent. de France* (1856) (3), 4, 679.

[4] *Loc. cit.* (1872) (5), 2, 29 (Bull.).

[5] *Loc. cit.* (1884) (6), 4, 76 and 124 (Bull.).

[6] Calwer's *Käferbuch* (1893), 397.

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PHILIPPINE COALS AS FUEL.

By ALVIN J. COX.

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INTRODUCTION.

While it may be true that the testing of fuels under boilers at best gives only approximately comparative results, nevertheless there is no degree of accuracy in assumptions such as that of Bazin,[1] who considered the practical steam-making capacity of a combustible material to be two-thirds of its found heating value. This capacity may vary from 80 per cent with the best anthracite down to 50 per cent or even less when a highly bituminous coal is used. The type of plant, the personnel and other important factors must be considered. The error in concluding that a coal high in evaporative power is on that account the best coal and conversely that a very cheap fuel necessarily must be cheap in the long run should be guarded against. The most satisfactory way in which a correct conclusion as to the respective commercial values of different coals can be arrived at is to make tests and then compare their performances as shown below.

There is no doubt that steam vessels can successfully use some of the Philippine coals. If others are too high in volatile combustible matter they unquestionably can be employed by mixing them with a certain amount of Australian coal and thus too rapid gasification be prevented. The Coast Guard and interisland ships now burn on the average 10 tons of Australian coal each per day or 300 tons per month. If they replace all or two-thirds by Philippine coal it would require only a simple calculation from the following data when the prices per ton are known, to determine the difference in cost.

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[1] *Rev. gen. de Chim.* (1904), **7**, 91; Rev. in *J. Am. Chem. soc.* (1905), **27**, 1333.

I know of but one trial of the commercial value of Philippine coal where complete data of the test were kept. This was made about two years ago at the Philippine Cold Storage and Ice Plant.[2] The test was as satisfactory as possible under the existing conditions; the results exceeded the anticipations of those in charge of the test and seemed to indicate "its equality with many other coals on the Manila market." However, the grates were not adapted to the fuel and much inconvenience was experienced because the decrepitated coal passed through the grate with the ash. Toward the end of the test, this ash was burned over again and after the second burning the analyses of this Bureau showed it to contain 62.6 per cent of combustible matter. No comparative tests were made with other coals.

In 1904 the United States Army transports *Chukong*, *Sacramento* and *Palawan* made runs on Batan coal and the reports in each case were favorable. The coal was easily fired, it burned well, the amount of soot was comparatively small, there was no great quantity of smoke, the content of ash was low and there was no clinker.

The object of the following investigation was to determine the steam-making value of the coals of the Philippine Islands, as measured by kilos of water evaporated per kilo of fuel when used under a boiler, as compared with the foreign coals offered on the market in this Archipelago; it has also been my purpose to make a comparative study of the individual coals as well as to convert into useful work the greatest possible percentage of heat units contained in each. Careful and complete records have been preserved of each test; therefore it should be possible for engineers to determine from the data which are given whether or not the conditions were those best suited to the coal under examination and when a price is established for these coals, these tables will form a basis of comparison not only as to the water evaporated per kilo of fuel, but also in regard to the water evaporated per peso of fuel cost. In commercial operations the all important question is to find the fuel which will run a plant with the least financial outlay.

A special grate was tried for some of the coals and an effort has been made to use a method of firing which would give the best results. As the supply of material at my disposal was limited, except in the case of Australian coal, only a small amount of preliminary experimenting could be done to determine the best practice in regard to firing and to gain information regarding the fuel before beginning the test. An engineer always needs experience with a coal to burn it in the most efficient manner. It will be noticed from the tables that in some cases the efficiency for the second run is slightly higher than that for the first, showing the benefit of the first day's experience; however, in no case is the difference much greater than the possible error from other sources. Several preliminary trials were made on the coal regularly used here for firing in order thoroughly to test the working condition of the apparatus. It would have been very desirable to have had duplicate determinations of the steaming quality of each coal, but this was not always possible with the supply on hand; nevertheless it is believed that all the results are complete and sufficiently reliable to show the nature and indicate the real fuel value of the coal; in fact it has recently been shown [3] that more than one test of a coal is superfluous. Seventy-seven first tests gave an average efficiency of 66.05 and seventy-seven second tests an average of 66.02 and thirty-two third tests one of 65.87.

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[2] *The Far Eastern Review*, January (1906).

It is evident that promiscuous tests made under different conditions are not at all comparable, for it would be impossible to discover whether the variation was due to the fuel, the apparatus or the manipulation. However, in the work done at this Bureau many factors have been eliminated by using the same plant [4] and the same personnel; the others have been carefully controlled by using the same apparatus and maintaining all manipulations and general conditions as nearly uniformly constant as possible, except where a change in the second test was to the advantage of the coal. With the variable factors eliminated, the coals can be directly compared.

DESCRIPTION OF APPARATUS AND METHODS EMPLOYED.

All instruments used were carefully standardized and every precaution taken to prevent the possibility of error. As the nature of the coals to be burned was so entirely different, two sets of grates were provided.

The one was of plain, single bars 1.5 centimeters in width and constructed to give an air space of 1.2 centimeters between each pair, or a ratio between air space and grate surface of 20 to 45. The other, constructed for these tests and used with some of the coals, was a perforated grate with round, tapering holes 1.25 centimeters in diameter at the top, the smallest dimension, averaging 25 per square decimeter and giving a ratio between air space and grate surface of 18 to 45.

The two boilers shown in Plate I are exactly alike, the following description applies to both; however, with one exception, the tests were made with the one on the right; they can afford only a clue as to the efficiency of the boilers. This was not sought, for there are no means of comparing the boilers with others fired with Philippine coal, or perhaps with themselves under different conditions. The boiler was thoroughly cleaned before beginning the test; it was in all cases used on the previous day so that the brickwork was thoroughly heated, and it was under full steam for some time on the day of the test before beginning the actual run. The gauge glass of each boiler was graduated into millimeters and calibrated independently with water at 30° C. These data were used to correct the water level between starting and stopping rather than by use of the pump.

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[3] Breckenridge, L. P., *U. S. G. S. Bull.* (1907), **325**, 32.

[4] The losses through radiation and conduction do not vary greatly for any given installation.

BOILER:

Kind, Babcock and Wilcox.

Nominal rating, 75 horsepower.

Type, water tube.

Tubes:

Number, 45.

Diameter
external, 10.16 centimeters.
internal, 9.48 centimeters.

Length exposed, 42.67 decimeters.

Drum:

Diameter, external, 9.15 decimeters.

Length, external, 58.4 decimeters.

Water-heating surface—	Square decimeters.
Of tubes	5,715.2
Of drum	748.8
Total	6,464.0

Steam gauge, Ashcroft's, graduated to 5 pounds on a 12-inch dial.

FURNACE:

Kind, Hand fired.

Height
front, 12.2 decimeters.
back, 8.3 decimeters.

Width, 9.90 decimeters.

Flue connecting to chimney:

Length, 18.3 decimeters.

Calorimeter, 49.4 square decimeters.

Grate:

Kind, gridiron bar or perforated as best adapted to the individual coal.

Width, 9.90 decimeters.

Length, 18.3 decimeters.

Area, 181.2 square decimeters.

Ratio of water heating surface to grate surface, 35.7: 1.

CHIMNEY:

Diameter, internal, 12.2 decimeters (4 English feet).

Height above grate, 30.5 meters (100 English feet).

Area, 38.33 square decimeters.

The stack was high enough in all cases to give the draft necessary for the coal in the condition used.

Draft, natural.

We have no economizer.

The exhaust main passes through a 200-horsepower Wainwright even-flow feed-water heater.

During all of these tests the steam was used to operate a large duplex steam pump, to drive the engine which furnishes the power to operate the air compressor, the vacuum pump, the refrigerating machine and many small motors, etc., for the laboratory and to supply live steam throughout the building. At first I intended to take switch-board readings, but the idea was given up as impracticable. Owing to the intermittent use of steam for other purposes such readings would necessarily be incomplete; but in Plates II to VII, I have given photographs of the volt meter and ammeter indicator diagrams. An estimation from these shows that an average of about 60 per cent of the steam produced was used by the engine, and 40 per cent for other purposes, including that condensed by radiation from the pipes. The equivalent evaporation per indicated horsepower was assumed as 25 kilos of water, because of the light and variable load of the engine.

The portable drop-lever Howe scales used in making the weighings were carefully standardized and found to be correct; the meter was fitted with a gauge and regulators so that it was calibrated from time to time by actually weighing the water passing through under the same head as it was fed into the boiler and no error was at any time detected in the registrations of the meter. If there was a slight error, being constant, it would affect alike all the tests and therefore be negligible in securing data for comparative purposes. The boiler feed pump was run intermittently and always at the same rate. The temperature of the water entering the boiler from the heater was determined by readings of a thermometer placed in a thermometer cup on the pipe just adjacent to the boiler. The steam gauges were tested by comparing with the test-gauge of the Crosby Steam Gauge and Valve Company, a standard instrument manufactured by Schäffer & Budenberg, Limited, and that used by the city boiler inspector. The only errors were in the initial setting of the needles. These in all cases were corrected at a pressure of 20 pounds per square inch by actual trial with a column of mercury. The damper was controlled by a lever passing over a graduated segment.

The chemical thermometers were of 550° C. capacity, and were calibrated by the *Physikalisch-Technische Reichsanstalt* in Charlottenburg, Germany. The temperatures of the flue gases were read from a high-grade mercury thermometer which was calibrated from these. The usual U tube, or inverted siphon of water, draft-gauge was used. One arm was open to the atmosphere and the other, by means of the proper connections was inserted into the draft to be tested. The difficulties of reading the gauge were reduced to a minimum by the looking-glass scale. The latter was accurately divided into millimeters so that the error of reading was not greater than a few units in the decimal. The scale was movable, which greatly facilitated the reading of it.

A Barrus' continuous, surface condenser calorimeter was on hand during several of the tests to determine the moisture in the steam. Steam nearly always carries water with it and thus the boiler is credited with having evaporated more water than is really the case. However, the results recorded in Table II have not been corrected for this since I was unable to determine the factor for all. It will be seen from the following table that the boiler of this Bureau produces steam which is very uniform in quality and as the results

of the tests are intended to be comparable only, it is permissible to omit this constant correction entirely. It was not convenient to attach the calorimeter close to the boiler. It was attached to the steam pipe 22 feet away and owing to the radiation from this pipe, even though all parts were well covered, the amount of moisture may be somewhat high.

The readings were made on several days during the firing of coal from three different sources and at different times of day, so that the greatest variations of load are represented. These readings are shown in *Table I.*

TABLE I.—*Steam calorimeter readings.*

Date, 1907.	Time after starting.		Steam-gauge pressure.	Readings of thermometer.	
				Upper.	Lower.
	h.	*m.*	*Kilos per sq. cm.*	°*C.*	°*C.*
June 19	5	20	7.8044	168	109
	5	45	7.8044	168	110
	6	10	7.8044	169	110
	6	35	7.1716	165	110
June 20	1	12	7.8044	167	109
	1	50	7.5232	167	109
	2	42	6.8200	164	110
	3	00	7.8044	168	110
	4	00	7.8044	168	110
	4	40	7.8044	167	109
	4	55	6.4685	161	108
	6	25	7.3825	166	111
June 21	2	40	7.5232	167	110
	3	20	7.1716	165.5	109.5
	5	50	7.5232	167.5	108.5
	6	20	7.5232	167	108.5
	6	30	7.1716	166	108
	6	45	7.8747	169	109
July 15	5	30	7.1716	168	110
	5	50	7.1716	168	110
July 16	1	30	7.1716	164	110
	1	50	7.4529	165	109
	4	40	7.3825	165	110
	5	05	7.1018	163	109
	5	20	7.8747	167	110.5
	6	15	7.5935	166	110

The average readings on all of these tests are, for the steam-gauge pressure 7.4501 kilograms per square centimeter (106 pounds per square inch), for the upper thermometer 166° (330°.8 F.), and for the lower thermometer 109°.4 (229° F.); the ranges for the thermometers being from 161° to 169° and from 108° to 110°.5, respectively. The normal for 166° may be taken as 139°.5 and the average cooling below this point is 30°.1. In order to compute the amount of moisture from the loss of heat shown, the number of degrees of cooling is divided by the coëfficient, which depends upon the specific heat of steam, representing the number of degrees of cooling due to 1 per cent of moisture. 30°.1 divided by the coëfficient given by Barrus[5] for 166°, which is 11°.66 (21° F.), gives 2.58 per cent. No correction has been made for the moisture produced by radiation from the apparatus itself.

Denton[6] has shown that it is seldom possible to operate a condensing calorimeter with the degree of exactness calculated for the instrumental error, namely, 1 per cent. There has always been found to exist accidental variation considerably in excess of the theoretical instrumental error, even Regnault's experiments, the results of which are presented in tabular form in most publications upon the properties of steam, being no exception in this respect. He has also shown that jets of steam show unmistakable change of appearance to the eye when steam varies less than 1 per cent, either in the direction of wetness or of superheating, from the condition of saturation. When a jet of steam flows from a boiler into the atmosphere under such conditions that very little loss of heat occurs through radiation, etc., the quantity of water if not too large, may be estimated from the color of the steam. If the jet is transparent close to the orifice, or is even a grayish-white color, the steam may be assumed to be so nearly dry that no portable condensing calorimeter will be capable of measuring the amount of moisture in it. If the jet is strongly white, the quantity of water, if it does not exceed 2 per cent, may roughly be estimated, but an amount in excess of this can be determined only with a calorimeter. Careful observations roughly corroborated the results given in Table I.

Analysis of the flue-gases.—The flue-gases were analyzed and for this purpose were drawn from the flue by means of a sampler such as is shown in the following figure:

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[5] *Trans. Am. Soc. M. E.* (1890), **11**, 795.

[6] *Ibid* (1899), **10**, 326.

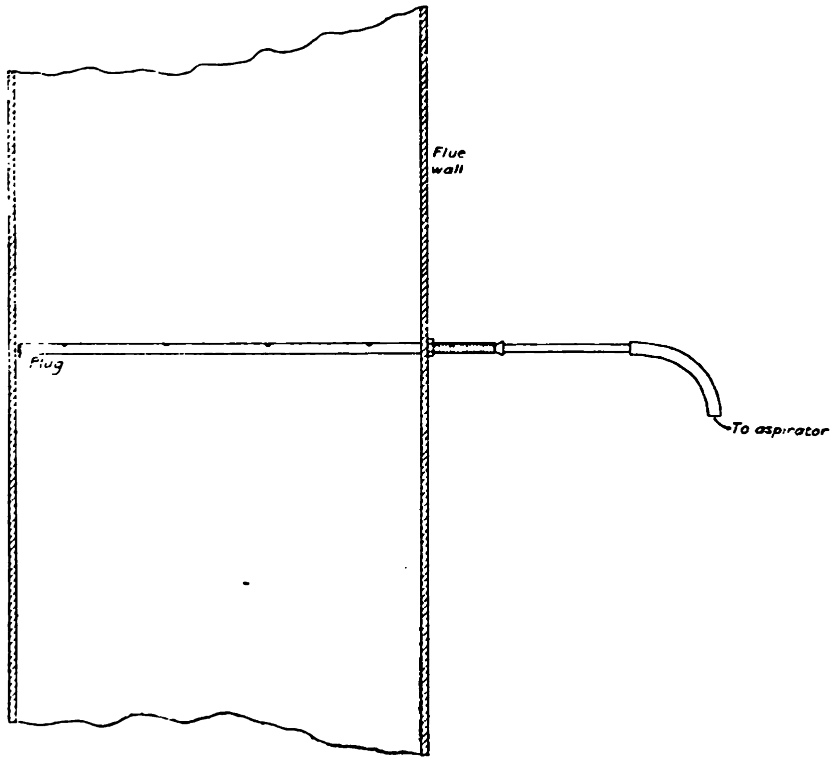

FIG. 1.

The apparatus consisted of an iron gas pipe of 1.5 centimeters internal diameter, passing through a suitable fixture attached to the shell of the chimney, long enough to extend across the flue and leave a few centimeters projecting. The inner end was capped and four holes 1.5 millimeters in diameter were bored, one 7.5 centimeters from each wall of the flue and the other two dividing the intervening distance into thirds. The two end holes were slightly enlarged (about 0.2 millimeter) to counter balance the increased draft in the middle of the chimney and the increased suction in the middle of the sampler when the gases were exhausted. A piece of glass tube was fitted into the open end of the iron pipe, by means of a tightly fitting plug, so that the end would reach to the middle of the perforated pipe. The apparatus was tested and proved to have tight joints. The sampler was inserted into the flue and the gases drawn off through the glass tube.[7] The holes were placed away from the current to prevent their being filled with soot. An aspirator was constructed of a large bottle fitted with the necessary siphon tubes.

A concentrated salt solution was used in the aspirator. It is realized that since the gases are somewhat soluble, this is not as accurate as their collection over mercury, but is probably as accurate as the sample itself.

Attention has been called to the fact that samples taken with an apparatus similar to this compared very favorably with those taken with the sampler recommended by the American Society of Mechanical Engineers. *U. S. G. S., P. P.* 48 (1906), 2, 311.

The solubility of carbon dioxide, the most soluble of the chimney gases, is shown by the following data:

Carbon dioxide was bubbled for twenty-four hours through water and a salt solution under identical conditions, at 28° C. and atmospheric pressure. For each part of water, 0.649 volume of gas was dissolved, while the volume for each part of the salt solution was only 21 per cent of this amount. There can be little doubt that these are the saturation values, for that obtained for water agrees remarkably well with the results of other investigators. Calculated from the interpolation formula of Naccari and Pagliani,[8] $a=1.5062-0.036511t+0.0002917t^2$, the value for water is 0.647.

The chimney gases were never bubbled through the salt solution and were in contact with the surface for a short time only, so that any error must be slight. The same salt solution was used throughout the experiments and after several months intermittent use and exposure to the air contained less than 2 per cent of the saturation value for pure water.

The exposed end of the glass tubing of the sampler was attached to the aspirator, the siphon started and the gases gradually drawn off. Between the aspirator and the sampler a Fresenius tower filled with cotton was imposed to remove the soot. By means of pinchcocks the removal of the flue gases was maintained at a constant rate. The aspirator was removed at will and a new one put in its place. This operation was continued for any number of successive hours. The various samples of gas thus obtained were analyzed and reported as the average for that period. The analyses were made according to standard chemical methods. The absorption medium for oxygen was an alkaline pyrogallol solution.[9]

The unconsumed constituents of the flue gases—viz, carbonic oxide, hydrocarbons and soot—may at times be great and represent a considerable percentage of the calorific value of a coal. However, the only combustible gas determined was carbon monoxide (CO). When this gas is found in any quantity it is quite probable that hydrogen and hydrocarbon gases are also present, but because of the difficulty of determining these in small amounts their percentages have not been ascertained.

Chemical analyses.—Nitrogen in the coal was determined by the regular Kjeldahl method and all other analyses were made according to standard chemical methods.

Determination of the calorific value of the coal.—In the calculation of the calorific value of the coal from the ultimate analysis, Dulong's formula in the form as given in 1899 in the report of the Committee on Coal Analysis,[10] appointed by the American Chemical Society, was used as follows:

$$\text{Calorific power}=8{,}080\text{C}+34{,}460(\text{H}-\tfrac{1}{8}\text{O})+2{,}250\text{S}.$$

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[8] *Gazzetta chim. ital.* (1880), **10**, 119; *Atti d. R. Ac. d. sc.*, Torino (1879–80), **15**, 279.

[9] It has been maintained (Franzen, H. *Ztschr. f. anorg. Ch.* (1908), **57**, 359.) since this work was done that this is not a satisfactory absorbent for analyzing gases where oxygen is present in large quantities, for the oxygen acts on the pyrogallol solution producing carbon monoxide (CO) which remains in the gas-rest and changes its composition. Alkaline sodium acid sulphite is recommended.

[10] *J. Am. Chem. Soc.* (1899), **21**, 1130.

The determination of the calorific value of the coal was made in a Berthelot-Mahler bomb calorimeter under a pressure of 20 atmospheres of oxygen. The constants used were those which had been carefully determined for previous work and the corrections for wire fused, niter, sulphur, etc., were made according to the usual methods.

Color of the smoke.—In judging the color of the smoke the standard Ringelmann scheme was followed. The smoke was observed against a clear sky and its color compared with the effect upon the eye of a 20-centimeter square, black-and-white grating held at 15 to 20 meters distance. Plate VIII is a photograph of the standard charts used. No. 1 is the pure white paper, and No. 6 in the series is entirely black; hence each intermediate proportion corresponds to a 20 per cent range. Plate IX shows a small section of the upper left-hand corner of each grating drawn to the exact scale.

Method of firing.—It was found that all of these coals, except where there was a large amount of clinker, worked best when fired in small quantities every four or five minutes with spreading stoking.

Method of starting and stopping.—The alternate method was used, that is, the boiler was thoroughly heated by a preliminary run of an hour or more; during the last twenty minutes or half an hour of this time the fire was fed with the coal to be tested, then allowed to burn low, cleaned, left level and the amount of live coal left on the grate estimated. At the same time the pressure of steam, the water in the boiler and other observations were taken, and the time recorded as the starting time. Fresh coal which had been previously weighed was now fired and the ash pit cleaned immediately. Before the end of the trial the fire was allowed to burn low, just as before the start, again cleaned and left in the same condition and with the same amount of coal on the grate as at the beginning of the test. This stage was recorded as the stopping time.

The temperature of the fire room was not recorded, because in the tropics fire rooms are so constructed that when in use they are entirely open and are practically the same as if the stationary boiler had merely a roof over it. The fire room temperature may be taken as that of the air.

The ash represents that actually removed. It was not practicable to recover the ash carried over the bridge and into the flues.

The individual tests give the other conditions governing the trials. I have been guided in reporting the data and the results of these evaporation tests by the form advised by the Boiler Test Committee of the American Society of Mechanical Engineers,[11] and have made these as complete as possible to enable anyone to make whatever other calculations, he may desire.

TESTS.

The following tables give the complete data obtained during and calculated from the various tests on coals made in this Bureau:

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[11] Code of 1899. Kent's Mechanical Engineers' Pocket-Book. New York (1903), 690; *Univ. of Ill. Bull.* (1906), **3**, 21; International Library of Technology **7**, 36; etc.

TABLE II.—*Steaming tests of Philippine coals and others offered for sale on the Manila market.*

[The black-faced figures over columns are code numbers of the American Society of Mechanical Engineers.]

No. of test.	Source of coal.	Commercial size of coal.	Date of trial.	Kind of grate used.	Duration of trial. 2	Average mercury barometer reading. Millimeters.	Average mercury barometer reading. Inches.	Average steam pressure by gauge— Per square centimeter.	Average steam pressure by gauge— Per square inch. 11	Average steam pressure absolute[a]— Per square centimeter.	Average steam pressure absolute[a]— Per square inch.
	Australia:				*Hours.*			*Kilos.*	*Pounds.*	*Kilos.*	*Pounds.*
1	Westwaldsend[j]	Lump and slack	June 20, 1907	Perforated	7	757.76	29.83	7.416	105.5	8.450	120.2
2	Do.[j]	do	June 21, 1907	Gridiron	7	757.39	29.82	7.249	103.1	8.283	117.8
3	Do.[j]	Selected lump	June 5, 1908	do	7	756.94	29.80	7.797	110.9	8.831	125.6
4	Liehzow Valley	Lump and slack	May 6, 1908	do	6	757.36	29.82	7.906	112.5	8.940	127.2
5	Do.[m]	do	May 7, 1908	do	6¾	758.48	29.86	7.571	107.7	8.605	122.4
	Japan:										
6	Yoshinotani (Karatsu), Kiushu Island	Lump	Apr. 22, 1908	do	7	758.03	29.84	7.831	111.4	8.865	126.1
7	Yubari (Hokkaido Province)	do	May 28, 1908	do	5	752.90	29.64	7.750	110.2	8.784	124.9
8	Borneo, Labuan	Pea to lump	July 15, 1907	do	7	756.94	29.80	6.834	97.2	7.868	111.9
9	do	do	July 16, 1907	do	6⅔	755.15	29.73	7.365	104.7	8.399	119.4
	Batan Island:										
10	Military reservation[o]	Lump and slack	Jan. 14, 1908	do	7¼	760.87	29.96	7.417	105.5	8.451	120.2
11	Do	do	Mar. 31, 1908	do	7 1/12	759.47	29.90	7.761	110.4	8.795	125.1
12	Do	do	Apr. 2, 1908	do	7	759.42	29.90	7.761	110.4	8.795	125.1
13	Military reservation, seam No. 4	Lump	May 27, 1908	do	7	754.20	29.69	7.656	108.9	8.690	123.6
14	Do.[p]	do	June 2, 1908	do	6⅚	759.00	29.88	7.862	111.8	8.896	126.5
15	Betts'	Lump and slack	Apr. 26, 1907	Perforated	4	758.85	29.88	4.471	63.6	5.505	78.3
16	Do	do	June 19, 1907	Gridiron	7	757.15	29.81	7.375	104.9	8.409	119.6
17	Cebu, Comansi	Lump	Nov. 14, 1907	do	5¼	757.86	29.84	7.547	107.3	8.581	122.0
18	do	do	Nov. 12, 1907	do	7⅙	758.93	29.88	7.706	109.6	8.740	124.3
19	Polillo[s]	do	Dec. 21, 1905	do	24	760.79	29.95	10.898	155.	11.932	169.7
20	China, Hongay[v]		Dec. 4, 1906		24	759.88	29.92	10.898	155.	11.932	169.7

Footnotes follow at the end of the table, pp. 317, 318.

TABLE II.—*Steaming tests of Philippine coals and others offered for sale on the Manila market*—Continued.

[For source and commercial size of coal, date of trial, kind of grate used, and duration of trial, see p. 311.]

No. of test.	Average force of draft in millimeters of water.		Average temperature of—					Proximate analysis of the coal.[b]				Color of ash.	Specific gravity of the coal.
	Between damper and boiler.	In ash pit.	External air.	Steam, calculated.	Feed water entering heater.	Feed water entering boiler from heater.	Escaping flue gases.	Fixed carbon.	Volatile combustible matter.	Moisture.	Ash.		
	12	14	15	17	18	20	21	32	33	34	35		
			°C.	°C.	°C.	°C.	°C.						
1	12	-------	29.3	171.8	28	79.2	360	50.94	34.23	2.80	12.03	Pinkish gray	Variable, average 1.40.
2	11	-------	29.0	171.0	28	80.3	364	50.94	34.23	2.80	12.03	do	Do.
3	9	1	29.2	173.6	29	72.4	378	52.43	36.64	1.74	9.19	Gray	Do.
4	8	-------	31.0	174.2	30	72.1	391	52.62	32.47	2.11	12.80	do	
5	9	-------	30.8	172.6	30	71.3	400	52.62	32.47	2.11	12.80	do	
6	-------	-------	31.7	173.8	28	74.8	333	48.33	37.53	1.83	12.31	do	Variable, average 1.32.
7	-------	-------	27.0	178.4	29	70.0	395	42.69	45.60	1.82	10.39	Buff	Variable, average 1.27.
8	11	-------	31.0	168.8	28	76.5	377	50.55	41.35	5.43	2.67	Light red	1.29
9	11	1	28.5	171.5	28	76.8	398¼	50.55	41.35	5.43	2.67	do	1.29
10	-------	-------	28.2	171.8	27	79.4	414	45.51	40.76	5.18	8.55	Reddish gray	Variable, average 1.30.
11	11	-------	31.2	173.5	29	78.9	310	49.41	38.26	5.88	6.45	Reddish brown	1.31
12	9	-------	30.8	173.5	29	78.9	334	50.30	38.99	5.87	4.84	do	1.30
13	9	-------	25.4	172.9	29	70.6	414	51.75	39.15	6.08	3.02	Reddish gray	1.31
14	9	-------	30.0	174.0	29	72.2	392	51.58	39.80	6.05	2.57	do	1.31
15	12½	1	30.7	154.7	29	77.9	406	38.33	36.56	18.03	7.08	Reddish brown	
16	12	-------	31.3	171.6	28	76.8	440	34.86	36.50	18.61	10.03	do	
17	9	-------	29.3	172.5	27	80.7	390	46.30	37.93	10.01	5.76	do	Average 1.32.
18	9	-------	30.0	178.2	27	84.8	342	46.27	37.95	9.94	5.84	do	Do.
19	21	-------	26.1	186.7	32	60.4	268	52.36	39.40	4.44	3.80	Brown	1.32
20	-------	-------	25.9	[x]262.2	29	88.3	[y]218	-------	-------	3.00	-------	-------	

Footnotes follow at the end of the table, pp. 317, 318.

TABLE II.—*Steaming tests of Philippine coals and others offered for sale on the Manila market*—Continued.

[For source and commercial size of coal, date of trial, kind of grate used, and duration of trial, see p. 311.]

No. of test.	Ultimate analysis of the coal.						Calorific value, in calories, of the coal as fired, calculated from the ultimate analysis.	Calorific value, by oxygen calorimeter.			Coal as fired.		Dry coal [c] consumed.			
													Total.	Per hour.	Per square decimeter of—	
	Carbon.	Hydrogen.	Oxygen.	Nitrogen.	Sulphur. 36	Ash.		Coal as fired.	Dry coal.[c] 50	Combustible.[c] 51	Total. 25	Per hour.	27	46	Grate surface per hour. 48	Water heating surface per hour.
								Calories.	*Calories.*	*Calories.*	*Kilos.*	*Kilos.*	*Kilos.*	*Kilos.*	*Kilos.*	*Kilos.*
1	70.16	4.11	1.43	12.18	0.09	12.03	6,572	6,614	6,805	7,766	1,474.0	210.6	1,432.7	204.7	1.13	0.0317
2	70.16	4.11	1.43	12.18	0.09	12.03	6,572	6,614	6,805	7,766	1,497.0	213.9	1,455.1	207.9	1.14	0.0321
3	72.36	4.87	1.57	11.86	0.15	9.19	7,018	6,983	7,107	7,840	1,233.8	176.3	1,212.3	173.2	0.96	0.0268
4	--------	--------	--------	--------	0.58	12.80	--------	6,987	7,138	8,211	1,174.4	195.7	1,149.6	191.6	1.05	0.0296
5	--------	--------	--------	--------	0.58	12.80	--------	6,987	7,138	8,211	1,334.5	197.7	1,306.3	193.5	1.06	0.0299
6	67.20	5.15	1.02	13.41	0.91	12.31	6,674	6,691	6,816	7,793	1,634.0	233.4	1,604.1	229.1	1.26	0.0354
7	72.98	4.20	1.19	11.13	0.11	10.39	6,867	7,127	7,222	8,072	1,072.9	214.6	1,058.7	211.7	1.17	0.0327
8	68.55	5.45	1.11	21.48	0.74	2.67	6,507	6,664	7,047	7,251	1,791.0	255.9	1,693.7	242.0	1.34	0.0374
9	68.55	5.45	1.11	21.48	0.74	2.67	6,507	6,664	7,047	7,251	1,791.0	269.0	1,693.7	254.0	1.40	0.0393
10	65.00	5.41	0.96	19.98	0.10	8.55	6,253	6,079	6,411	7,046	1,947.8	259.7	1,846.9	246.2	1.36	0.0381
11	67.63	4.54	1.11	20.18	0.09	6.45	6,162	6,298	6,691	7,184	1,587.6	224.1	1,494.2	210.9	1.16	0.0326
12	68.78	4.62	1.13	20.54	0.09	4.84	6,269	6,359	6,755	7,125	1,562.6	223.2	1,470.9	210.1	1.16	0.0325
13	69.23	5.41	1.16	21.04	0.14	3.02	6,555	6,584	7,010	7,243	1,572.5	224.6	1,476.9	211.0	1.16	0.0326
14	69.55	5.43	1.17	21.09	0.19	2.57	6,554	6,610	7,035	7,233	1,404.3	205.5	1,319.3	193.1	1.07	0.0299
15	52.04	5.36	0.93	33.75	0.84	7.08	4,617	4,647	5,669	6,205	1,134.0	288.5	929.5	232.4	1.28	0.0359
16	51.06	5.29	0.91	31.53	1.21	10.03	4,618	4,560	5,602	6,390	2,313.4	330.5	1,882.9	269.0	1.48	0.0416
17	63.35	5.90	1.43	22.79	0.77	5.76	6,187	6,071	6,746	7,208	1,227.4	223.2	1,104.5	200.8	1.10	0.0309
18	63.34	5.89	1.43	22.67	0.83	5.84	6,192	6,069	6,739	7,206	1,566.0	208.8	1,410.3	188.4	1.04	0.0291
19	69.10	4.87	1.33	20.67	0.23	3.80	6,377	6,752	7,065	7,358	18,717.4	779.9	17,886.3	745.3	[f] 1.64	[g] 0.0401
20	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	19,755.6	--------	19,162.9	--------	--------	--------

Footnotes follow at the end of the table, pp. 317, 318.

TABLE II.—*Steaming tests of Philippine coals and others offered for sale on the Manila market*—Continued.

[For source and commercial size of coal, date of trial, kind of grate used, and duration of trial, see p. 311.]

No. of test.	Combustibles [c] consumed.				Total ash and refuse.[d]	Clinker in ash and refuse.	Ash and refuse referred to dry coal.[d]	Analysis of ash.				Analysis of clinker.	
	Total.	Per hour.	Per square decimeter of—										
			Grate surface per hour.	Water heating surface per hour.				Fixed carbon.	Volatile combustible matter.	Moisture.	Ash.	Carbon.	Earthy matter.
	30	17		49	28	29	31						
	Kilos.	*Kilos.*	*Kilos.*	*Kilos.*	*Kilos.*	*Per cent.*	*Per cent.*						
1	1,255.4	179.4	0.99	0.0277	196.9	25.1	13.73	27.50	1.00	None.	71.50	12.30	87.70
2	1,275.0	182.1	1.00	0.0282	198.2	29.3	13.62	25.40		None.	74.60	7.86	92.14
3	1,099.0	157.0	0.87	0.0243	152.4	20.0	12.57	21.41	2.19	0.13	76.27	10.00	90.00
4	999.3	166.6	0.92	0.0257	197.3	Practically none[l]	17.16	20.92	1.57	0.26	77.25		
5	1,135.5	168.2	0.93	0.0260	207.3	Practically none[l]	15.86	19.68	1.44	0.20	78.68		
6	1,403.0	200.4	1.10	0.0309	253.1	39.8	15.78	14.00	1.29	0.22	84.49	[n]31.08	63.52
7	947.3	189.5	1.05	0.0293	168.7	33.6	15.96	34.05	8.24	0.44	57.27	5.20	94.80
8	1,645.9	235.1	1.30	0.0363	115.2	11.8	6.81	51.98	7.89	1.79	38.34		
9	1,645.9	246.9	1.36	0.0382	109.8	None.	6.48	52.51	7.16	2.90	37.43		
10	1,680.4	224.0	1.23	0.0346	367.9	17.9	19.93				55.76	1.26	98.74
11	1,391.8	196.5	1.08	0.0304	326.1	2.6	21.84	65.50	7.60	3.80	23.11		
12	1,394.6	199.2	1.10	0.0308	269.0	3.2	18.27	65.48	5.18	2.79	25.85		
13	1,429.1	204.2	1.13	0.0315	201.5	9.0	13.66	71.35	6.16	2.22	20.27	3.63	96.37
14	1,283.2	187.8	1.04	0.0290	162.9	7.8	12.35	65.46	7.93	2.20	24.41		
15	849.2	212.3	1.17	0.0328	87.3	8.0	9.40	46.06	11.28	6.20	36.46	2.48	97.52
16	1,650.8	235.8	1.30	0.0364	281.5	7.8	14.95	53.17	8.73	4.06	34.04	[r]0.00	100.00
17	1,033.8	188.0	1.04	0.0290	70.8	Practically none	6.41	15.89	8.35	1.91	73.85		
18	1,318.9	175.9	0.97	0.0272	99.3	Practically none	7.03	19.76	9.45	2.38	68.41		
19	17,178.8	716.1	[t]1.58	[u]0.0885	1,016.5	8.5	5.68	62.60		2.40	35.00	12.30	87.70
20					8,166.6		16.58						

Footnotes follow at the end of the table, pp. 317, 318.

TABLE II.—*Steaming tests of Philippine coals and others offered for sale on the Manila market*—Continued.

[For source and commercial size of coal, date of trial, kind of grate used, and duration of trial, see p. 311.]

No. of test.	The coal, equivalent to the combustible material in the total refuse.	Percentage of the coal as fired actually consumed.	Percentage of smoke as observed.	Analyses of the flue gases[e] (numbers give per cent by volume).				Water fed to boiler.		Equivalent from and at 100° C.[f]	Factor of evaporation.	Horse-power developed.[g]	Percentage of builder's rated horse-power developed.
				Carbon dioxide (CO_2).	Oxygen (O).	Carbon monoxide (CO).	Nitrogen (by difference) (N).	Liters.	Kilos.				
			77	84	85	86	88		57	58	60	65	
	Kilos.												
1	58.7	96.02	39.0	9.80	6.75	0.64	83.81	8,995	8,961.5	10,538	1.1759	96.2	128
2	49.1	96.71	39.0	10.00	6.38	0.11	83.51	8,908	8,875.	10,432	1.1754	95.2	127
3	36.3	97.06	[k]26.1	7.00	9.70	0.00	83.30	8,075	8,045.	9,453	1.1750	86.3	115
4	51.7	95.59	29.7	11.40	5.30	0.40	82.90	6,725	6,700.	7,862	1.1734	83.7	112
5	51.0	96.18	25.0	10.94	5.88	0.29	82.89	7,345	7,317.5	8,579	1.1724	81.2	108
6	72.0	95.60	41.8	11.09	5.29	0.43	83.19	6,870	6,844.	8,055	1.1769	73.5	98
7	57.2	94.67	20.8	11.10	5.30	0.43	83.17	6,125	6,102.	7,169	1.1749	91.6	122
8	71.5	96.01	47.7	10.54	5.54			8,321	8,290.	9,734	1.1742	88.8	118
9	77.4	95.68	37.9	12.07	3.80			8,114	8,084.	9,505	1.1757	91.1	121
10	189.0	90.30	29.0	11.20	3.97	0.00	84.83	7,720	7,691.	9,058	1.1773	77.1	103
11	286.6	81.94	21.2	7.75	7.05	0.75	84.45	5,855	5,833.	6,853	1.1749	61.8	82
12	229.0	85.34	20.9	5.87	7.80	0.85	85.48	5,975	5,953.	6,994	1.1749	63.8	85
13	179.5	88.58	17.3	10.96	6.88	0.61	81.55	8,600	8,568.	10,064	1.1746	91.8	122
14	131.0	90.67	15.8	8.89	9.18	0.06	81.87	8,015	7,985.	9,384	1.1752	88.2	117
15	75.8	93.32	(q)	11.30	6.95	0.25	81.50	4,327	4,311.	5,019	1.1642	80.2	107
16	269.0	88.36	(q)	10.80	7.26	0.25	81.69	8,795	8,762.	10,302	1.1757	94.0	125
17	21.0	98.29	19.7	9.70	6.60	1.42	82.28	6,260	6,236.5	7,347	1.1780	85.3	114
18	35.6	97.73	17.8			High.		7,700	7,671.5	9,041	1.1785	77.0	103
19	711.6	96.40	20.0						[v]108,000.5	127,106	1.1769	338.4	169
20									96,910.5	[x]114,597	1.1825	305.0	

Footnotes follow at the end of the table, pp. 317, 318.

TABLE II.- *Steaming tests of Philippine coals and others offered for sale on the Manila market*—Continued.

For source and commercial size of coal, date of trial, kind of grate used, and rial, see p. 311.]

No. of test.	Equivalent evaporation of water from and at 100° C.								Efficiency of boiler including grate, in per cent, based on the chemical analysis.	Average humidity of air entering furnace, percentage of the saturated value for the temperature.	Rainfall during test, in millimeters.	Prevailing wind during test.		State of the weather.[l]
	Per hour.		Per kilo of—			Per kilo actually consumed[b]—								
	Kilos. 63	Per square decimeter of water-heating surface. 64	Coal as fired. 69	Dry coal. 70	Combustible. 71	Of coal as fired.	Of dry coal.	Of combustible.	73			Direction.	Force, in kilometers per hour.	
1	1,505.4	0.232	7.150	7.356	8.394	7.446	7.661	8.742	57.99	76.2	3.9	WSW.	21.7	o (gusty winds).
2	1,490.3	0.230	6.970	7.169	8.182	7.206	7.411	8.460	56.53	77.1	0.0	WSW.	18.8	o (gusty winds at intervals).
3	1,350.4	0.209	7.661	7.798	8.601	7.894	8.034	8.862	58.86	77.1	0.0	WSW.	12.0	o
4	1,310.3	0.203	6.694	6.839	7.867	7.003	7.154	8.230	51.40[e]	65.6	0.0	ENE.	8.5	o
5	1,271.0	0.197	6.429	6.568	7.555	6.684	6.828	7.855	49.36	68.0	0.0	W.	10.1	c
6	1,150.7	0.178	4.930	5.022	5.741	5.157	5.253	6.005	39.53	51.2	0.0	W.	10.8	b
7	1,433.8	0.222	6.682	6.771	7.568	7.058	7.152	7.994	50.30	82.7	6.7	SSW.	31.8	o (squally).
8	1,390.6	0.215	5.435	5.747	5.914	5.661	5.986	6.160	43.75	69.3	0.0	WSW., SW.	13.0	o, c
9	1,425.7	0.220	5.307	5.611	5.775	5.546	5.865	6.035	42.72	79.6	1.4	SW.	24.6	o (gusty winds at intervals).
10	1,207.7	0.187	4.650	4.904	5.390	5.148	5.431	5.969	41.04	70.2	0.0	NNW.	9.6	c
11	967.5	0.150	4.317	4.586	4.924	5.268	5.597	6.009	37.62	51.6	0.0	SE.	15.1	c
12	999.1	5.154	4.476	4.755	5.015	5.245	5.572	5.876	37.76	55.1	0.0	SE.	16.3	c (gusty winds at intervals p. m.).
13	1,437.7	0.222	6.400	6.815	7.041	7.225	7.693	7.948	52.15	92.2	28.1	SSE.	12.8	o, r (drizzle and rain at intervals).
14	1,373.3	0.213	6.682	7.113	7.313	7.370	7.845	8.065	54.24	75.2	0.0	SW.	13.2	o
15	1,254.7	0.194	4.426	5.400	5.910	4.743	5.786	6.333	51.10	59.8	0.0	W., WNW.	9.6	b
16	1,471.7	0.227	4.453	5.471	6.241	5.040	6.192	7.063	52.40	67.1	0.0	SW.	18.9	c (thunderstorm).
17	1,335.8	0.207	5.985	6.651	7.106	6.089	6.766	7.230	52.89	64.3	0.0	WSW.	10.2	b
18	1,205.5	0.187	5.775	6.411	6.855	5.907	6.560	7.014	51.01	64.9	0.0	NNW., E.	11.2	c
19	5,296.0	0.285	[r]6.791	[r]7.106	[r]7.399	7.044	7.872	7.675	53.95	81.7	1.9	Variable.	5.4	c, o
20	1,775.0	----------	[s]5.806	5.985	----------	----------	----------	----------	----------	82.8	0.2	SW., ESE.	3.4	c

Footnotes follow at the end of the table, pp. 317, 318.

FOOTNOTES TO TABLE II, PP. 311–316.

[a] The barometric pressure was taken as uniformly equal to 1.034 kilograms per sq. cm. (14.7 lbs. per sq. in.) (30 inches in mercury).

[b] Mostly analyzed by Mr. H. S. Walker after the method of Cox, *This Journal Sec. A*, (1907), **2**, 41.

[c] Calculated from the proximate analysis.

[d] This does not include the ash carried over the bridge wall.

[e] Analyzed by Mr. M. Vivencio according to standard methods.

[f] The steam pressure and the temperature of the feed water must be considered. The total heat in calories from water at 0° C. of the saturated steam at 7.416 kilograms per square centimeter (105.5 lbs. per sq. in.) is 658.9 and that of the feed water is 28. These together with the kilos of water, 8,961.5, fed to the boiler, give the equivalent from and at 100° C. at atmospheric pressure as $\frac{658.9-28}{536.5}$ (factor of evaporation) $\times 8{,}961.5 = 10{,}538$ kilos, 536.5 calories being taken as the latent heat of steam. For convenience these numbers are taken from Peabody's "Tables of the Properties of Saturated Steam," which are generally accepted by engineers. They may be calculated from the following formulæ on which the greater part of all tables is based:

$\lambda = 606.5 + 0.305t$ (v. Regnault, *Mém. de l'Acad.* (1847), **21**, 635.)

$\lambda = 589.5 + 0.7028t - 0.0031947t^2 + 0.000008447t^3$ (Winkelmann, A., *Wied. Ann.* (1880), **9**, 208, 358.)

$r = 589.5 - 0.2972t - 0.0032147t^2 + 0.000008147t^3$ (Winkelmann.)

where λ = the total heat of saturated steam through which the liquid at 0° is changed into steam at any temperature t° and where r = the latent heat of saturated steam, through which the liquid at any temperature t° is changed into steam at t°.

[g] 15.65 kilos of water evaporated per hour from and at 100° C. equals 1 horsepower.

[h] Calculated from the composition of the ash and the clinker, the calorific value of pure carbon and the fuel ratio and the calorific value of the coal.

[i] b = blue sky; c = cloudy sky; o = overcast sky; r = rain.

[j] This is the laboratory fuel furnished by the Bureau of Supply. It is "double-screened and picked twice." It was purchased on Circular Proposal No. 248 at a contract price delivered in Manila, piled in the coal sheds and yards of the Civil Government at ₱10.75 per ton of 2,240 pounds.

[k] The tendency of native firemen is to scatter coal high and in most of these tests there is undoubtedly needless smoke as well as some loss of heat energy. In this test exceptional effort was made to prevent the formation of smoke. In spite of the fact that this is lump coal which always produces less smoke, the percentage still remains high, which indicates that it is impossible to burn this Australian coal with our setting without a considerable production of smoke.

[l] About 4 per cent of a soft incipient clinker which falls to pieces in dropping from the door of the furnace.

[m] This test shows the personal variation in firemen. A new man was put on; he could not keep his fire regular and the result was a somewhat low evaporation and at times high chimney temperature and low steam pressure.

[n] The clinker also contained 0.3 per cent of moisture and 5.1 per cent of volatile combustible matter showing that some coal was mechanically inclosed.

[o] This coal does not represent the vein for it had evidently lain in the tunnel where it had been water soaked and considerably silted over. The ash content and clinker-forming ability are therefore high as compared with the run of this coal. It was very difficult to obtain an accurate laboratory sample. The ash shown by the chemical analysis is considerably less than that of the coal actually fired.

[p] In the use of this fuel, the coal on the grate was not disturbed from start to finish. It was alternately semi-coked and spread-fired, and the result is more complete combustion, lower chimney temperature, and greater evaporation.

[q] Practically no smoke (under 10 per cent).

[r] This actually gives a negative value due to the oxidation of the iron.

[s] The test from which these data were calculated for purposes of comparison was made at the Insular Cold Storage and Ice Plant. *Far Eastern Review* (1906) 2, 223.

[t] 452.9 square decimeters of grate surface, 46½ per cent air space.

[u] 18,580 square decimeters of water heating surface.

[v] When the preceding numbers are compared with this they should probably be increased by a few per cent. Experience has shown that the larger the plant the less the loss due to radiation and that unaccounted for, and the water apparently evaporated is therefore larger by this amount.

[w] On December 4, 1906, the Manila Electric Railroad and Light Company made a 24-hour evaporative test on their boilers under regular operating condition with a mixture of Chinese and Australian coal using 19,756 and 30,402 kilos, respectively. The following day under as nearly identical conditions as possible a 24-hour evaporative test was made on Australian coal alone. They report that when using the mixture it was necessary to get assistance from one of the banked boilers when cleaning the fires and that during the peak of the evening load, straight Australian coal was used. Since the object of these tests was to determine the relative evaporative power of the two kinds of fuel, and since a poor coal owing to physical conditions often burns better when mixed with a better coal, it is at least fair to the Chinese coal to take the proportional part of the test on December 4, correcting for the amount of Australian coal used on the basis of the test of December 5. Data obtained by difference are never as satisfactory as direct data, but since I have not been able to make a test of Chinese coal and our information with regard to it is meager, it is thought that these data will give a fair idea of coal from this source and will represent in a general way the quality of the coal which may reach the Manila market from the China coast.

[x] 75°.5 superheating. The following calculations and results are based on the assumption of no superheating, for in the above tests this heat was lost through the stack. Recent investigation has shown that the specific heat of superheated steam is not constant, that it is approximately 0.65 for 55°.5 C. (100° F.) superheat and 0.75 for 111° C. (200° F.) superheat. Using these values, 9½ per cent of additional fuel was saved by the superheating to the degree named.

[y] The temperature was reduced to this value by the use of a superheater.

[z] The data of the Manila Electric Railroad and Light Company, show 8.00 for coal from Westwaldsend, Australia, which is 4 per cent higher than my selected sample and 10 per cent higher than my average sample of the same variety. In their test of Australian coal there was 82°.2 superheating. Using the values given in x, 11 per cent additional fuel was saved by this amount of superheating.

I am indebted to the Weather Bureau for the detailed data regarding the weather.

TABLE III.—*Heat balance or distribution of the heating value of the combustible.*

No. of test	1		2		3		4		5		6	
Source of the coal	Australia, Westwalsend.		Australia, Westwalsend.		Australia, Westwalsend.		Australia, Lichzow Valley.		Australia, Lichzow Valley.		Japan, Yoshinotani (Karatsu) Kiushu Island.	
Commercial size	Lump and slack.		Lump and slack.		Selected lump.		Lump and slack.		Lump and slack.		Lump.	
Factors.	Calories.	Per cent.	Calories.	Per cent.	Calories.	Per cent.	Calories.	Per cent.	Calories.	Per cent.	Calories.	Per cent.
1. Heat absorbed by the boiler[a]	4,504	57.99	4,390	56.53	4,615	58.86	4,221	51.40	4,053	49.36	3,080	39.53
2. Loss due to moisture in the coal[b]	24	0.31	24	0.31	15	0.19	19	0.23	19	0.23	15	0.19
3. Loss due to moisture formed by the burning of hydrogen[c]	171	2.20	171	2.20	162	2.04					224	2.87
4. Loss due to heat carried away in dry chimney gases[d]	1,300	16.75	1,344	17.32	2,079	26.55	1,290	15.70	1,286	15.65	1,027	13.18
5. Loss due to incomplete combustion of carbon[e]	253	3.26	45	.58	0	0.00	135	1.64	103	1.25	146	1.87
6. Loss due to combustible in ash and refuse	309	3.98	256	3.29	231	2.94	362	4.41	314	3.82	343	4.40
7. Loss due to unconsumed hydrogen and hydrocarbons, to heating the moisture in the air, to radiation and unaccounted for; some of these losses may be separately itemized if data are obtained from which they may be calculated	1,205	15.51	1,536	19.77	738	9.42					2,958	37.96
Total		100.		100.		100.						100.
Total heat value of 1 unit of combustible	7,766		7,766		7,840		8,211		8,211		7,793	

Footnotes follow the table on pp. 321, 322.

TABLE III.—*Heat balance or distribution of the heating value of the combustible*—Continued.

No. of test	7		8		9		10		11		12		13	
Source of the coal	Japan, Yubari Hokkaido Province.		Borneo, Labuan.		Borneo, Labuan.		Batan Island, Military Reservation.		Batan Island, Military Reservation.		Batan Island, Military Reservation.		Batan Island, Military Reservation, seam No. 4.	
Commercial size	Lump.		Pea to lump.		Pea to lump.		Lump and slack		Lump and slack		Lump and slack		Lump.	
Factors.	Calories.	Per cent.	Calories.	Per cent.	Calories.	Per cent.	Calories.	Per cent.	Calories.	Per cent.	Calories.	Per cent.	Calories.	Per cent.
1. Heat absorbed by the boiler[a]	4,060	50.30	3,173	43.75	3,098	42.72	2,892	41.04	2,701	37.62	2,690	37.76	3,777	52.15
2. Loss due to moisture in the coal[b]	12	0.15	21	0.29	22	0.30	46	0.65	47	0.65	47	0.66	51	0.70
3. Loss due to moisture formed by the burning of hydrogen[c]	189	2.34	183	2.52	186	2.56	197	2.79	129	1.79	133	1.87	191	2.63
4. Loss due to heat carried away in dry chimney gases[d]	1,342	16.63	1,346	18.42	1,216	16.80	1,202	17.07	1,276	17.75	1,720	24.15	1,444	19.95
5. Loss due to incomplete combustion of carbon[e]	158	1.96	-------	-------	-------	-------	0	0.00	362	5.04	526	7.38	222	3.06
6. Loss due to combustible in ash and refuse	430	5.33	280	3.99	313	4.32	684	9.70	1,299	18.06	1,045	14.66	828	11.42
7. Loss due to unconsumed hydrogen and hydrocarbons, to heating the moisture in the air, to radiation and unaccounted for; some of these losses may be separately itemized if data are obtained from which they may be calculated	1,881	23.29	2,248	31.08	2,416	33.30	2,025	28.75	1,370	19.09	964	13.52	730	10.09
Total	-------	100.	-------	100.	-------	100.	-------	100.	-------	100.	-------	100.	-------	100.
Total heat value of 1 unit of combustible	8,072	-------	7,251	-------	7,251	-------	7,046	-------	7,184	-------	7,125	-------	7,243	-------

Footnotes follow the table on pp. 321, 322.

No. of test	14		15		16		17		18		19		20	
Source of the coal	Batan Island, Military Reservation, seam No. 4.		Batan Island, Betts'.		Batan Island, Betts'.		Cebu, Comansi.		Cebu, Comansi.		Polillo.		China, Hongay.	
Commercial size	Lump.		Lump and slack		Lump and slack		Lump.		Lump.		Lump.			
Factors.	Calories.	Per cent.	Calories.	Per cent.	Calories.	Per cent.	Calories.	Per cent.	Calories.	Per cent.	Calories.	Per cent.	Calories.	Per cent.
1. Heat absorbed by the boiler[a]	3,923	54.24	3,171	51.10	3,348	52.40	3,812	52.89	3,678	51.04	3,970	53.95		
2. Loss due to moisture in the coal[b]	49	0.68	181	2.92	200	3.13	88	1.22	85	1.18	34	0.46		
3. Loss due to moisture formed by the burning of hydrogen[c]	187	2.58	77	1.24	94	1.47	207	2.87	198	2.74	142	1.93		
4. Loss due to heat carried away in dry chimney gases[d]	1,661	22.97	914	14.72	1,012	15.83	1,303	18.08						
5. Loss due to incomplete combustion of carbon[e]	27	0.37	66	1.06	68	1.06	513	7.11						
6. Loss due to combustible in ash and refuse	675	9.33	414	6.68	744	11.64	123	1.71	164	2.27	265	3.60		
7. Loss due to unconsumed hydrogen and hydrocarbons, to heating the moisture in the air, to radiation and unaccounted for; some of these losses may be separately itemized if data are obtained from which they may be calculated	711	9.83	1,382	22.28	924	14.47	1,162	16.12						
Total		100.		100.		100.		100.						
Total heat value of 1 unit of combustible	7,233		6,205		6,390		7,208		7,206		7,358			

[a] This value in calories = the water evaporated from and at 100°C × 536.5.

[b] This refers to the hygroscopic moisture only. The loss in calories = $W\ [100-t+536.5+0.48\ (T-100)]$ where W is the per cent of moisture referred to the combustible; t the fire-room temperature and T the temperature of the flue gases.

[c] This loss in calories = $9H\ [100-t+536.5+0.48\ (T-100)]$ where H is the proportional part by weight of hydrogen in the dry coal.

[d] This loss in calories = the weight of the flue gases per unit weight of combustible × 0.24 $(T-t)$. This value is only approximate, as the sampling and the reading of the temperatures of the chimney gases are liable to considerable error. For this reason, as well as for the fact that there are many factors

that can not be determined, the heat balance itself is only approximate. When the ultimate analysis of a fuel is known, from a knowledge of the products of combustion, the air required with no excess for complete combustion is easily calculated. When there is more or less imperfect combustion and more or less excess of air entering a furnace the problem of calculating the weight of the flue-gases per kilo of combustible becomes more complex. A great many formulæ have been proposed to do this, but they seldom agree well, owing to the inaccuracies above mentioned. Kent, Steam boiler Economy (First Ed.), 32, shows that when the flue-gas analyisis is known the total amount of air supplied per unit of fuel is $3.032 \left\{\frac{N}{CO_2+CO}\right\} \times C$ where N, CO_2 and CO are the per cent by volume of nitrogen, carbon monoxide and carbon dioxide in the flue gases, and C the proportional part by weight of carbon in the fuel. The weight of flue gases will be *one* less the proportional part of ash in the fuel x, more than this, i.e., $3.032 \left\{\frac{N}{CO_2+CO}\right\} \times C+(1-x)$ where $(1-x)$ is the combustible and moisture in the fuel. The Stirling Consolidated Boiler Co. (A Book on Steam for Engineers (1906), 183, New York) recommend as a check that the weight of air supplied per unit weight of fuel$=11.52\times\frac{CO_2+1/2\ CO+O}{CO_2+CO}\times C+34.56H$ where O is the per cent by volume of oxygen in the flue gases and H is the available hydrogen ($H-\frac{1}{8}O$) in the fuel. The average of the results obtained by the use of these two formulæ has been used. In most cases the variation from this was less than 2 per cent.

[*] This loss in calories$=5{,}705\times\frac{CO}{CO+CO_2}\times C$ where the quantity 5,705 is the number of calories generated by burning one unit weight of carbon contained in carbon monoxide to carbon dioxide (calculated from the numbers of J. Thomsen, Thermo-chemische Untersuchungen (1882), 2, 52, 283 and 288) and as before CO and CO_2 are the per cent by volume in the flue gases, and C the proportional part by weight of carbon in the combustible.

TABLE IV.—*Observations in detail of the tests of coals from Australia, Japan, Borneo, and the Philippine Islands.*

A.—FIRST TEST OF COAL FROM WESTWALDSEND, AUSTRALIA—77 FIRINGS DURING 7-HOUR TEST.

[Test No. 1, Table II.]

Time after starting.	Steam pressure gauge.		Temperature of flue gases, base of stack.	Average composition of flue gases, in per cent.			Kilos of coal burned—		Kilos of water fed to boiler—		Fire raked or sliced, time after starting.	Cleaned fire, time after starting.
	Kilos per square centimeter.	Pounds per square inch.		CO₂	O₂	CO	During period.	Total.	During period.	Total.		
											h. m.	*h. m.*
Beginning	7.172	102	360	8.0	8.0	1.5						0 00
¼ hour	7.312	104	340				60	60	325	325		
½ hour	7.453	106	355				60	120	325	650		
¾ hour	7.172	102	360				55	175	325	975		
1 hour	7.523	107	346				55	230	325	1,300		
1¼ hours	7.523	107	360				55	285	325	1,625		
1½ hours	7.523	107	357				55	340	325	1,950		
1¾ hours	7.382	105	351				55	395	325	2,275		
2 hours	7.664	109	343				50	445	325	2,600		
2¼ hours	7.453	106	363				50	495	325	2,925		
2½ hours	7.172	102	363				50	545	325	3,250	2 17	
2¾ hours	7.523	107	355				50	595	325	3,575		
3 hours	7.804	111	349				50	645	325	3,900		
3¼ hours	7.593	108	349	10.0	7.5	0.0	50	695	325	4,225	3 18	
3½ hours	7.312	104	355				50	745	325	4,550		
3¾ hours	7.523	107	355				50	795	325	4,875		
4 hours	7.734	110	340				50	845	325	5,200		
4¼ hours	7.382	105	338				50	895	325	5,525		
4½ hours	7.172	102	357				50	945	325	5,850		
4¾ hours	7.031	100	332				30	975	325	6,175		
5 hours	6.890	98	355				60	1,035	200	6,375		5 16
5¼ hours	7.453	106	357				60	1,095	300	6,675	5 04	
5½ hours	7.312	104	351	12.5	4.1	0.0	60	1,155	350	7,025		
5¾ hours	7.312	104	427				60	1,215	350	7,375		
6 hours	7.945	113	435				60	1,275	350	7,725		
6¼ hours	7.593	108	401				60	1,335	350	8,075		
6½ hours	7.804	111	371				60	1,395	350	8,425		
6¾ hours	7.523	107	355				60	1,455	350	8,775		
7 hours	6.820	97					19	1,474	186.5	8,961.5		7 00
Total	215.075	3,059	10,080				1,474		8,961.5			
Average	7.416	105.5	360				52.6		316.4			

TABLE IV.—*Observations in detail of the tests of coals*—Continued.

B.—SECOND TEST OF COAL FROM WESTWALDSEND, AUSTRALIA—84 FIRINGS DURING 7-HOUR TEST.

[Test No. 2, Table II.]

Time after starting.	Steam pressure gauge.		Temperature of flue gases, base of stack.	Average composition of flue gases, in per cent.			Kilos of coal burned—		Kilos of water fed to boiler—		Fire raked or sliced, time after starting.	Cleaned fire, time after starting.
	Kilos per square centimeter.	Pounds per square inch.		CO_2	O_2	CO	During period.	Total.	During period.	Total.		
											h. m.	*h. m.*
Beginning	6.961	99	360	10.0	5.4	0.0						0 00
¼ hour	7.031	100	400				60	60	325	325		
½ hour	7.453	106	355				60	120	325	650		
¾ hour	7.664	109	350				50	170	325	965	0 42	
1 hour	7.382	105	350				50	220	325	1,300		
1¼ hours	7.593	108	385				50	270	325	1,625		
1½ hours	7.664	109	355				50	320	325	1,950		
1¾ hours	7.593	108	350				50	370	325	2,275		
2 hours	7.523	107	335				50	420	325	2,600		
2¼ hours	7.172	102	350				50	470	325	2,925		
2½ hours	7.734	110	360				50	520	325	3,250		
2¾ hours	7.453	106	365	10.2	6.3	0.0	50	570	325	3,575		
3 hours	7.804	111	350				50	620	325	3,900		
3¼ hours	7.172	102	335				50	670	325	4,225		
3½ hours	7.172	102	340				50	720	325	4,550		
3¾ hours	7.664	109	340				50	770	325	4,875		
4 hours	7.875	112	340				50	820	325	5,200		
4¼ hours	7.172	102	380				60	880	300	5,500		4 15
4½ hours	6.961	99	360				60	940	200	5,700		
4¾ hours	6.539	93	350				60	1,000	250	5,950	4 31 4 35 4 39	
5 hours	5.976	85	360				60	1,060	250	6,200	4 53 4 57	
5¼ hours	5.625	80	390	9.8	7.7	0.4	60	1,120	250	6,450		
5½ hours	5.976	85	450				60	1,180	375	6,825		
5¾ hours	7.593	108	520				60	1,240	375	7,200		
6 hours	7.312	104	410				60	1,300	375	7,575		
6¼ hours	7.523	107	340				60	1,360	375	7,950		
6½ hours	7.172	102	330				60	1,420	375	8,325		
6¾ hours	7.875	112	330				60	1,480	375	8,700		
7 hours	7.593	108	320				17	1,497	175	8,875		7 00
Total	210.227	2,990	10,560				1,497		8,875			
Average	7.249	103.1	364				53½		317			

TABLE IV.—*Observations in detail of the tests of coals*—Continued.

C.—FIRST TEST OF LUMP COAL FROM WESTWALDSEND, AUSTRALIA—79 FIRINGS DURING 7-HOUR TEST.

[Test No. 3, Table II.]

Time after starting.	Steam pressure gauge.		Temperature of flue gases, base of stack.	Average composition of flue gases, in per cent.			Kilos of coal burned—		Kilos of water fed to boiler—		Fire raked or sliced, time after starting.	Cleaned fire, time after starting.
	Kilos per square centimeter.	Pounds per square inch.		CO_2	O_2	CO	During period.	Total.	During period.	Total.		
											h. m.	*h. m.*
Beginning	7.172	102	375	4.6	10.8	0.0	-----	-----	-----	-----	-----	0 00
¼ hour	7.312	104	383				45	45	200	200	-----	-----
½ hour	7.875	112	410				45	90	250	450	-----	-----
¾ hour	8.156	116	400				45	135	250	700	-----	-----
1 hour	8.086	115	381				45	180	300	1,000	-----	-----
1¼ hours	8.015	114	384				45	225	300	1,300	-----	-----
1½ hours	8.086	115	388				45	270	300	1,600	-----	-----
1¾ hours	7.523	107	360				45	315	300	1,900	-----	-----
2 hours	7.523	107	368				45	360	300	2,200	-----	-----
2¼ hours	7.734	110	368				45	405	300	2,500	-----	-----
2½ hours	8.437	120	388				45	450	300	2,800	-----	-----
2¾ hours	7.875	112	355				45	495	300	3,100	2 42	-----
3 hours	7.804	111	364				45	540	300	3,400	-----	-----
3¼ hours	7.242	103	365				45	585	300	3,700	-----	-----
3½ hours	8.086	115	363				45	630	300	4,000	-----	-----
3¾ hours	7.734	110	411	9.4	8.6	0.0	45	675	300	4,300	-----	-----
4 hours	7.523	107	390				45	720	300	4,600	-----	-----
4¼ hours	7.242	103	383				45	765	300	4,900	-----	-----
4½ hours	7.804	111	370				45	810	300	5,200	-----	-----
4¾ hours	7.523	107	392				45	855	300	5,500	-----	-----
5 hours	7.664	109	367				45	900	300	5,800	-----	4 54
5¼ hours	8.226	117	396				45	945	300	6,100	-----	-----
5½ hours	7.523	107	388				45	990	300	6,400	-----	-----
5¾ hours	8.015	114	376				45	1,035	300	6,700	-----	-----
6 hours	7.664	109	396				45	1,080	300	7,000	-----	-----
6¼ hours	8.086	115	370				45	1,125	300	7,300	-----	-----
6½ hours	8.226	117	370				45	1,170	300	7,600	-----	-----
6¾ hours	7.804	111	359				45	1,215	300	7,900	-----	-----
7 hours	8.156	116	351				18.8	1,233.8	145	8,045	-----	7 00
Total	226.116	3,216	10,971	-----	-----	-----	1,233.8	-----	8,045	-----	-----	-----
Average	7.797	110.9	378	-----	-----	-----	44.1	-----	287	-----	-----	-----

TABLE IV.—*Observations in detail of the tests of coals*—Continued.

D.—FIRST TEST OF COAL FROM LICHZOW VALLEY, AUSTRALIA—44 FIRINGS DURING 6-HOUR TEST.

[Test No. 4, Table II.]

Time after starting.	Steam pressure gauge.		Temperature of flue gases, base of stack.	Average composition of flue gases, in per cent.			Kilos of coal burned—		Kilos of water fed to boiler—		Fire raked or sliced, time after starting.	Cleaned fire, time after starting.
	Kilos per square centimeter.	Pounds per square inch.		CO_2	O_2	CO	During period.	Total.	During period.	Total.		
											h. m.	*h. m.*
Beginning	7.453	106	380	11.4	6.6	0.6	------	------	------	------	------	0 00
¼ hour	7.875	112	385				55	55	250	250	------	------
½ hour	8.086	116	365				50	105	250	500	------	------
¾ hour	7.593	108	375				50	155	250	750	------	------
1 hour	7.734	110	385				50	205	300	1,050	------	------
1¼ hours	7.734	110	355				50	255	300	1,350	------	------
1½ hours	7.593	108	345				50	305	300	1,650	1 21	------
1¾ hours	7.875	112	395				50	355	300	1,950	------	------
2 hours	8.086	115	415				50	405	300	2,250	------	------
2¼ hours	8.086	115	380				50	455	300	2,550	------	------
2½ hours	7.593	108	350				50	505	300	2,850	------	------
2¾ hours	8.226	117	393				50	555	300	3,150	------	------
3 hours	7.734	110	423				50	605	300	3,450	------	------
3¼ hours	7.804	111	392	11.4	5.8	0.2	40	645	300	3,750	------	3 09
3½ hours	8.297	118	400				55	700	300	4,050	------	------
3¾ hours	8.086	115	415				55	755	300	4,350	------	------
4 hours	8.226	117	428				50	805	300	4,650	------	------
4¼ hours	8.226	117	413				50	855	300	4,950	------	------
4½ hours	8.015	114	410				50	905	300	5,250	------	------
4¾ hours	7.523	107	390				50	955	200	5,450	------	4 43
5 hours	7.312	104	380				50	1,005	250	5,700	------	------
5¼ hours	8.226	117	385				50	1,055	300	6,000	------	------
5½ hours	7.875	112	395				50	1,105	300	6,300	------	------
5¾ hours	8.507	121	430				50	1,155	300	6,600	------	------
6 hours	7.875	112	------				19.4	1,174.4	100	6,700	------	6 00
Total	197.640	2,812	9,384	------	------	------	1,174.4	------	6,700	------	------	------
Average	7.906	112.5	391	------	------	------	48.9	------	279	------	------	------

TABLE IV.—*Observations in detail of the tests of coals*—Continued.

E.—SECOND TEST OF COAL FROM LICHZOW VALLEY, AUSTRALIA—60 FIRINGS DURING 6¾-HOUR TEST.

[Test No. 5, Table II.]

Time after starting.	Steam pressure gauge.		Temperature of flue gases, base of stack.	Average composition of flue gases, in per cent.			Kilos of coal burned—		Kilos of water fed to boiler—		Fire raked or sliced, time after starting.	Cleaned fire, time after starting.
	Kilos per square centimeter.	Pounds per square inch.		CO_2	O_2	CO	During period.	Total.	During period.	Total.		
											h. m.	*h. m.*
Beginning	7.031	100	320	11.8	3.4	0.4	-----	-----	-----	-----	-----	0 00
¼ hour	7.101	101	325				60	60	300	300	-----	-----
½ hour	7.453	106	385				55	115	300	600	-----	-----
¾ hour	7.593	108	435				50	165	300	900	0 31	-----
1 hour	7.943	113	427				50	215	300	1,200	-----	-----
1¼ hours	8.156	116	425				50	265	300	1,500	-----	-----
1½ hours	7.312	104	435				50	315	200	1,700	1 21	-----
1¾ hours	7.242	103	445				50	365	200	1,900	-----	-----
2 hours	7.242	103	470				50	415	200	2,100	1 49	-----
2¼ hours	7.804	111	517				50	465	200	2,300	-----	-----
2½ hours	8.015	114	507				50	515	200	2,500	-----	-----
2¾ hours	8.929	127	420				50	565	200	2,700	-----	-----
3 hours	7.734	110	395				50	615	300	3,000	-----	-----
3¼ hours	8.015	114	400	10.2	8.0	0.2	50	665	300	3,300	-----	-----
3½ hours	7.523	107	397				50	715	300	3,600	-----	-----
3¾ hours	7.453	106	395				50	765	300	3,900	-----	-----
4 hours	7.734	110	400				50	815	300	4,200	-----	3 52
4¼ hours	7.523	107	407				50	865	300	4,500	-----	-----
4½ hours	7.453	106	400				50	915	300	4,800	-----	-----
4¾ hours	7.242	103	390				50	965	300	5,100	-----	-----
5 hours	7.664	109	365				50	1,015	300	5,400	-----	-----
5¼ hours	7.523	107	360				50	1,065	300	5,700	-----	-----
5½ hours	7.734	110	348				50	1,115	300	6,000	-----	-----
5¾ hours	7.453	106	364				50	1,165	300	6,300	-----	-----
6 hours	7.945	113	340				50	1,215	300	6,600	-----	-----
6¼ hours	7.101	101	335				50	1,265	300	6,900	6 05	-----
6½ hours	6.961	99	-----				50	1,315	300	7,200	-----	-----
6¾ hours	7.101	101	-----	-----	-----	-----	19¼	1,334¼	117.6	7,317.6	-----	6 42
Total	211.982	3,015	10,407	-----	-----	-----	1,334¼	-----	7,317.6	-----	-----	-----
Average	7.571	107.7	400	-----	-----	-----	49.4	-----	271.	-----	-----	-----

TABLE IV.—*Observations in detail of the tests of coals*—Continued.

F.—TEST OF COAL FROM YOSHINOTANI (KARATSU), KIUSHU ISLAND, JAPAN—61 FIRINGS DURING 7-HOUR TEST.

[Test No. 6, Table II.]

Time after starting.	Steam pressure gauge.		Temperature of flue gases, base of stack.	Average composition of flue gases, in per cent.			Kilos of coal burned—		Kilos of water fed to boiler—		Fire raked or sliced, time after starting.	Cleaned fire, time after starting.
	Kilos per square centimeter.	Pounds per square inch.		CO_2	O_2	CO	During period.	Total.	During period.	Total.		
											h. m.	*h. m.*
Beginning	7.804	111	330	11.2	5.4	0.6	------	------	------	------	------	0 00
¼ hour	8.015	114	340				70	70	200	200	------	------
½ hour	8.015	114	333				70	140	200	400	------	------
¾ hour	7.945	113	320				60	200	250	650	------	------
1 hour	7.734	110	270				60	260	250	900	------	------
1¼ hours	7.875	112	335				60	320	250	1.150	------	------
1½ hours	7.523	107	359				60	380	300	1,450	------	------
1¾ hours	7.875	112	325				60	440	300	1,750	1 45	------
2 hours	7.875	112	338				60	500	300	2,050	------	------
2¼ hours	7.875	112	385				60	560	300	2,350	------	------
2½ hours	8.015	114	360				60	620	300	2,650	------	------
2¾ hours	7.523	107	335				60	680	300	2,950	------	------
3 hours	7.453	106	310				60	740	0	2,950	------	2 49
3¼ hours	8.015	114	325	11.2	4.6	0.4	60	800	250	3,200	------	------
3½ hours	7.593	108	285				60	860	250	3,450	------	------
3¾ hours	8.015	114	345				60	920	300	3,750	------	------
4 hours	7.945	113	335				60	980	300	4,050	------	------
4¼ hours	7.593	108	320				60	1,040	300	4,350	------	------
4½ hours	7.945	113	305				60	1,100	300	4,650	------	------
4¾ hours	7.875	112	315				60	1,160	0	4,650	------	4 38
5 hours	7.875	112	325				60	1,220	250	4,900	------	------
5¼ hours	8.367	119	355	10.8	5.6	0.2	60	1,280	250	5,150	------	------
5½ hours	7.734	110	365				60	1,340	300	5,450	------	------
5¾ hours	7.875	112	335				60	1,400	300	5,750	------	------
6 hours	7.593	108	340				60	1,460	250	6,000	------	------
6¼ hours	7.523	107	325				60	1,520	300	6,300	------	------
6½ hours	7.875	112	346				60	1,580	300	6,600	6 16	------
6¾ hours	8.086	115	365				54	1,634	100	6,700	------	6 33
7 hours	7.664	109	339				0	1,634	144	6,844	------	7 00
Total	227.100	3,230	9,665	------	------	------	1,634	------	6,844	------	------	------
Average	7.831	111.4	333	------	------	------	58.4	------	244.3	------	------	------

TABLE IV.—*Observations in detail of the tests of coals*—Continued.

G.—FIRST TEST OF COAL FROM YUBARI (HOKKAIDO PROVINCE) JAPAN—59 FIRINGS DURING 5-HOUR TEST.

[Test No. 7, Table II.]

Time after starting.	Steam pressure gauge.		Temperature of flue gases, base of stack.	Average composition of flue gases, in per cent.			Kilos of coal burned—		Kilos of water fed to boiler—		Fire raked or sliced, time after starting.	Cleaned fire, time after starting.
	Kilos per square centimeter.	Pounds per square inch.		CO_2	O_2	CO	During period.	Total.	During period.	Total.		
											h. m.	*h. m.*
Beginning	8.226	117	335	9.0	9.2	0.4	------	------	------	------	------	0 00
¼ hour	7.804	111	354				60	60	325	325	------	------
½ hour	7.945	113	360				60	120	325	650	------	------
¾ hour	8.086	115	354				55	175	325	975	------	------
1 hour	8.437	120	350				55	230	325	1,300	------	------
1¼ hours	8.086	115	380				55	285	325	1,625	------	------
1½ hours	7.593	108	354				55	340	325	1,950	------	------
1¾ hours	7.875	112	355				55	395	325	2,275	------	------
2 hours	7.172	102	360				30	425	200	2,475	------	1 57
2¼ hours	7.312	104	370				60	485	325	2,800	------	------
2½ hours	7.312	104	364				60	545	325	3,125	------	------
2¾ hours	7.031	100	410				55	600	325	3,450	2 36 2 45	------
3 hours	7.242	103	460				55	655	325	3,775	------	------
3¼ hours	7.312	104	438	5.0	13.0	0.6	55	710	325	4,100	------	------
3½ hours	7.804	111	445				55	765	325	4,425	------	------
3¾ hours	8.156	116	448				55	820	325	4,750	------	------
4 hours	7.875	112	454				55	875	325	5,075	------	------
4¼ hours	7.804	111	460				55	930	325	5,400	------	------
4½ hours	7.382	105	447				55	985	325	5,725	------	------
4¾ hours	8.015	114	420				55	1,040	325	6,050	------	------
5 hours	8.297	118	377				32.9	1,072.9	52	6,102	------	5 00
Total	162.766	2,315	8,295	------	------	------	1,072.9	------	6,102	------	------	------
Average	7.750	110.2	395	------	------	------	53.6	------	305	------	------	------

[q] Practically no smoke (under 10 per cent).

[r] This actually gives a negative value due to the oxidation of the iron.

[s] The test from which these data were calculated for purposes of comparison was made at the Insular Cold Storage and Ice Plant. *Far Eastern Review* (1906) 2, 223.

[t] 452.9 square decimeters of grate surface, 46½ per cent air space.

[u] 18,580 square decimeters of water heating surface.

[v] When the preceding numbers are compared with this they should probably be increased by a few per cent. Experience has shown that the larger the plant the less the loss due to radiation and that unaccounted for, and the water apparently evaporated is therefore larger by this amount.

[w] On December 4, 1906, the Manila Electric Railroad and Light Company made a 24-hour evaporative test on their boilers under regular operating condition with a mixture of Chinese and Australian coal using 19,756 and 30,402 kilos, respectively. The following day under as nearly identical conditions as possible a 24-hour evaporative test was made on Australian coal alone. They report that when using the mixture it was necessary to get assistance from one of the banked boilers when cleaning the fires and that during the peak of the evening load, straight Australian coal was used. Since the object of these tests was to determine the relative evaporative power of the two kinds of fuel, and since a poor coal owing to physical conditions often burns better when mixed with a better coal, it is at least fair to the Chinese coal to take the proportional part of the test on December 4, correcting for the amount of Australian coal used on the basis of the test of December 5. Data obtained by difference are never as satisfactory as direct data, but since I have not been able to make a test of Chinese coal and our information with regard to it is meager, it is thought that these data will give a fair idea of coal from this source and will represent in a general way the quality of the coal which may reach the Manila market from the China coast.

[x] 75°.5 superheating. The following calculations and results are based on the assumption of no superheating, for in the above tests this heat was lost through the stack. Recent investigation has shown that the specific heat of superheated steam is not constant, that it is approximately 0.65 for 55°.5 C. (100° F.) superheat and 0.75 for 111° C. (200° F.) superheat. Using these values, 9½ per cent of additional fuel was saved by the superheating to the degree named.

[y] The temperature was reduced to this value by the use of a superheater.

[z] The data of the Manila Electric Railroad and Light Company, show 8.00 for coal from Westwaldsend, Australia, which is 4 per cent higher than my selected sample and 10 per cent higher than my average sample of the same variety. In their test of Australian coal there was 82°.2 superheating. Using the values given in x, 11 per cent additional fuel was saved by this amount of superheating.

I am indebted to the Weather Bureau for the detailed data regarding the weather.

TABLE III.—*Heat balance or distribution of the heating value of the combustible.*

No. of test	1		2		3		4		5		6	
Source of the coal	Australia, Westwalsend.		Australia, Westwalsend.		Australia, Westwalsend.		Australia, Lichzow Valley.		Australia, Lichzow Valley.		Japan, Yoshinotani (Karatsu) Kiushu Island.	
Commercial size	Lump and slack.		Lump and slack.		Selected lump.		Lump and slack.		Lump and slack.		Lump.	
Factors.	Calories.	Per cent.	Calories.	Per cent.	Calories.	Per cent.	Calories.	Per cent.	Calories.	Per cent.	Calories.	Per cent.
1. Heat absorbed by the boiler[a]	4,504	57.99	4,390	56.53	4,615	58.86	4,221	51.40	4,053	49.36	3,080	39.53
2. Loss due to moisture in the coal[b]	24	0.31	24	0.31	15	0.19	19	0.23	19	0.23	15	0.19
3. Loss due to moisture formed by the burning of hydrogen[c]	171	2.20	171	2.20	162	2.04					224	2.87
4. Loss due to heat carried away in dry chimney gases[d]	1,300	16.75	1,344	17.32	2,079	26.55	1,290	15.70	1,286	15.65	1,027	13.18
5. Loss due to incomplete combustion of carbon[e]	253	3.26	45	.58	0	0.00	135	1.64	103	1.25	146	1.87
6. Loss due to combustible in ash and refuse	309	3.98	256	3.29	231	2.94	362	4.41	314	3.82	343	4.40
7. Loss due to unconsumed hydrogen and hydrocarbons, to heating the moisture in the air, to radiation and unaccounted for; some of these losses may be separately itemized if data are obtained from which they may be calculated	1,205	15.51	1,536	19.77	738	9.42					2,958	37.96
Total		100.		100.		100.						100.
Total heat value of 1 unit of combustible	7,766		7,766		7,840		8,211		8,211		7,793	

Footnotes follow the table on pp. 321, 322.

TABLE III.—*Heat balance or distribution of the heating value of the combustible*—Continued.

No. of test	7		8		9		10		11		12		13	
Source of the coal	Japan, Yubari Hokkaido Province.		Borneo, Labuan.		Borneo, Labuan.		Batan Island, Military Reservation.		Batan Island, Military Reservation.		Batan Island, Military Reservation.		Batan Island, Military Reservation, seam No. 4.	
Commercial size	Lump.		Pea to lump.		Pea to lump.		Lump and slack		Lump and slack		Lump and slack		Lump.	
Factors.	Calories.	Per cent.	Calories.	Per cent.	Calories.	Per cent.	Calories.	Per cent.	Calories.	Per cent.	Calories.	Per cent.	Calories.	Per cent.
1. Heat absorbed by the boiler[a]	4,060	50.30	3,173	43.75	3,098	42.72	2,892	41.04	2,701	37.62	2,690	37.76	3,777	52.15
2. Loss due to moisture in the coal[b]	12	0.15	21	0.29	22	0.30	46	0.65	47	0.65	47	0.66	51	0.70
3. Loss due to moisture formed by the burning of hydrogen	189	2.34	183	2.52	186	2.56	197	2.79	129	1.79	133	1.87	191	2.68
4. Loss due to heat carried away in dry chimney gases[d]	1,342	16.63	1,346	18.42	1,216	16.80	1,202	17.07	1,276	17.75	1,720	24.15	1,444	19.95
5. Loss due to incomplete combustion of carbon[c]	158	1.96					0	0.00	362	5.04	526	7.38	222	3.06
6. Loss due to combustible in ash and refuse	430	5.33	280	3.99	313	4.32	684	9.70	1,299	18.06	1,045	14.66	828	11.42
7. Loss due to unconsumed hydrogen and hydrocarbons, to heating the moisture in the air, to radiation and unaccounted for; some of these losses may be separately itemized if data are obtained from which they may be calculated	1,881	23.29	2,248	31.03	2,416	33.30	2,025	28.75	1,370	19.09	964	13.52	730	10.09
Total		100.		100.		100.		100.		100.		100.		100.
Total heat value of 1 unit of combustible	8,072		7,251		7,251		7,046		7,184		7,125		7,243	

Footnotes follow the table on pp. 321, 322.

TABLE IV.—*Observations in detail of the tests of coals*—Continued.

K.—SECOND TEST OF COAL FROM THE MILITARY RESERVATION, BATAN ISLAND—64 FIRINGS DURING 7 1/12-HOUR TEST.

[Test No. 11, Table II.]

Time after starting.	Steam pressure gauge.		Temperature of flue gases, base of stack.	Average composition of flue gases, in per cent.			Kilos of coal burned—		Kilos of water fed to boiler—		Fire raked or sliced, time after starting.	Cleaned fire, time after starting.
	Kilos per square centimeter.	Pounds per square inch.		CO_2	O_2	CO	During period.	Total.	During period.	Total.		
											h. m.	*h. m.*
Beginning	8.367	119	310	7.8	7.8	0.6	------	------	------	------	------	0 00
¼ hour	7.945	113	315				60	60	225	225	------	------
½ hour	7.664	109	305				60	120	225	450	------	------
¾ hour	7.664	109	305				60	180	225	675	------	------
1 hour	7.734	110	315				60	240	225	900	------	------
1¼ hours	7.734	110	360				60	300	225	1,125	1 07	------
1½ hours	7.875	112	365				60	360	225	1,350	------	------
1¾ hours	7.875	112	340				60	420	225	1,575	------	------
2 hours	7.593	108	320				60	480	225	1,800	1 50	------
2¼ hours	7.734	110	300	7.5	7.3	0.9	60	540	225	2,025	------	------
2½ hours	7.374	110	300				60	600	200	2,225	------	2 26
2¾ hours	7.172	102	282				60	660	225	2,450	------	------
3 hours	7.804	111	315				60	720	225	2,675	------	------
3¼ hours	7.875	112	315				55	775	200	2,875	------	------
3½ hours	8.226	117	290				55	830	200	3,075	------	------
3¾ hours	7.523	107	300				55	885	200	2,275	------	------
4 hours	7.945	113	290				55	940	200	3,475	3 54	------
4¼ hours	7.664	109	310				55	995	200	3,675	------	------
4½ hours	7.875	112	320				55	1,050	200	3,875	------	------
4¾ hours	7.882	105	288	8.2	6.2	1.1	55	1,105	200	4,075	------	------
5 hours	7.945	113	310				55	1,160	200	4,275	------	------
5¼ hours	7.664	109	300				55	1,215	200	4,475	------	------
5½ hours	8.015	114	310				55	1,270	200	4,675	------	------
5¾ hours	7.734	110	288				55	1,325	200	4,875	------	------
6 hours	7.523	107	310				55	1,380	200	5,075	------	------
6¼ hours	7.804	111	300				55	1,435	200	5,275	------	------
6½ hours	7.734	110	300				55	1,490	200	5,475	------	------
6¾ hours	7.523	107	310				55	1,545	200	5,675	------	------
7 hours	7.734	110	310				42.6	1,587.6	158	5,833	------	------
7 1/12 hours	------	------	------				0	1,587.6	0	5,833	------	7 05
Total	225.061	3,201	8,983	------	------	------	1,587.6	------	5,833	------	------	------
Average	7.761	110.4	310	------	------	------	56.7	------	208.3	------	------	------

TABLE IV.—*Observations in detail of the tests of coals*—Continued.

L.—THIRD TEST OF COAL FROM THE MILITARY RESERVATION, BATAN ISLAND—56 FIRINGS DURING 7-HOUR TEST.

[Test No. 12, Table II.]

Time after starting.	Steam pressure gauge.		Temperature of flue gases, base of stack.	Average composition of flue gases, in per cent.			Kilos of coal burned—		Kilos of water fed to boiler—		Fire raked or sliced, time after starting.	Cleaned fire, time after starting.
	Kilos per square centimeter.	Pounds per square inch.		CO_2	O_2	CO	During period.	Total.	During period.	Total.		
											h. m.	*h. m.*
Beginning	7.804	111	300	5.0	8.0	1.4	------	------	------	------	------	0 00
¼ hour	7.664	109	330				60	60	225	225	------	------
½ hour	7.734	110	330				60	120	225	450	------	------
¾ hour	7.945	113	345				60	180	225	675	0 43	------
1 hour	7.945	113	355				60	240	225	900	------	------
1¼ hours	7.875	112	330				60	300	225	1,125	------	------
1½ hours	7.664	109	315				60	360	225	1,315	------	------
1¾ hours	7.875	112	320				60	420	225	1,575	------	------
2 hours	7.804	111	290				60	480	225	1,800	------	------
2¼ hours	8.015	114	285				60	540	225	2,025	------	------
2½ hours	7.312	104	435				60	600	225	2,250	------	------
2¾ hours	8.015	114	380				55	655	225	2,475	------	------
3 hours	7.875	112	345				55	710	225	2,700	------	------
3¼ hours	8.086	115	320				55	765	225	2,925	------	------
3½ hours	7.875	112	350				55	820	225	3,150	------	------
3¾ hours	7.945	113	310	8.8	6.8	0.4	55	875	225	3,875	------	------
4 hours	7.382	105	290				55	930	200	3,575	------	------
4¼ hours	8.297	118	350				55	985	200	3,775	------	------
4½ hours	7.312	104	340				55	1.040	200	3,975	------	------
4¾ hours	7.875	112	315				55	1,095	200	4,175	------	------
5 hours	8.015	114	330				55	1.150	200	4.375	------	------
5¼ hours	7.523	107	300				55	1,205	200	4,575	------	------
5½ hours	7.664	109	325				55	1,260	200	4,775	------	------
5¾ hours	7.734	110	330				55	1,315	200	4,975	------	5 35
6 hours	7.523	107	390				55	1,370	200	5,175	------	------
6¼ hours	7.664	109	340				55	1,425	200	5,375	6 03 6 12	------ ------
6½ hours	7.593	108	335				55	1,470	200	5,575	6 25	------
6¾ hours	7.664	109	365				55	1,535	200	5,775	6 35	------
7 hours	7.382	105	340				27.6	1,562.6	178	5,953	------	7 00
Total	225.061	3,201	9,690	------	------	------	1,562.6	------	5,953	------	------	------
Average	7.761	110.4	334	------	------	------	55.8	------	212.6	------	------	------

TABLE IV.—*Observations in detail of the tests of coals*—Continued.

M.—FIRST TEST OF LUMP COAL FROM THE MILITARY RESERVATION, BATAN ISLAND—76 FIRINGS DURING 7-HOUR TEST.

[Test No. 13, Table II.]

Time after starting.	Steam pressure gauge.		Temperature of flue gases, base of stack.	Average composition of flue gases, in per cent.			Kilos of coal burned—		Kilos of water fed to boiler—		Fire raked or sliced, time after starting.	Cleaned fire, time after starting.
	Kilos per square centimeter.	Pounds per square inch.		CO_2	O_2	CO	During period.	Total.	During period.	Total.		
											h. m.	*h, m.*
Beginning	7.172	102		11.6	6.2	0.6						0 00
¼ hour	7.664	109					65	65	310	310		
½ hour	7.664	109	405				60	135	310	620		
¾ hour	7.593	108	395				60	195	310	930		
1 hour	7.523	107	430				60	255	310	1,240	0 55	
1¼ hours	7.804	111	440				60	315	310	1,550		
1½ hours	7.523	107	450				60	375	310	1,860		
1¾ hours	7.382	105	445				55	430	310	2,170		
2 hours	7.734	110	448				55	485	310	2,480		
2¼ hours	7.664	109	397				55	540	310	2,790		
2½ hours	7.453	106	430				60	600	310	3,100		2 25
2¾ hours	7.242	103	442	11.0	7.2	0.4	60	660	310	3,410		
3 hours	7.523	107	465				55	715	310	3,720		
3¼ hours	7.382	105	440				55	770	310	4,030		
3½ hours	7.523	107	435				55	825	310	4,340		
3¾ hours	7.734	110	420				55	880	310	4,650		
4 hours	8.226	117	405				55	935	310	4,960		
4¼ hours	7.875	112	378				55	990	310	5,270		
4½ hours	8.307	118	385				55	1,045	310	5,580		
4¾ hours	7.382	105	370	0.3	7.3	0.8	55	1,100	310	5,890		
5 hours	7.945	113	385				55	1,155	310	6,200		
5¼ hours	7.804	111	400				50	1,205	310	6,510		5 15
5½ hours	7.312	104	400				60	1,265	310	6,820		
5¾ hours	7.523	107	380				60	1,325	310	7,130		
6 hours	8.507	121	390				55	1,380	310	7,440		
6¼ hours	8.015	114	400				55	1,435	310	7,750		
6½ hours	7.664	109	412				55	1,490	310	8,060		
6¾ hours	7.664	109	415				55	1,545	310	8,370		
7 hours	7.242	103	432				27.5	1,572.5	198	8,568		7 00
Total	220.046	3,158	11,194				1,572.5		8,568			
Average	7.656	108.9	414½				56.1		306			

TABLE IV.—*Observations in detail of the tests of coals*—Continued.

N.—SECOND TEST OF LUMP COAL FROM THE MILITARY RESERVATION, BATAN ISLAND—89 FIRINGS DURING 6⅚-HOUR TEST.

[Test No. 14, Table II.]

Time after starting.	Steam pressure gauge.		Temperature of flue gases, base of stack.	Average composition of flue gases, in per cent.			Kilos of coal burned—		Kilos of water fed to boiler—		Fire raked or sliced, time after starting.	Cleaned fire, time after starting.
	Kilos per square centimeter.	Pounds per square inch.		CO_2	O_2	CO	During period.	Total.	During period.	Total.		
											h. m.	*h. m.*
Beginning	8.156	116	400	10.0	7.4	0.2	----	----	----	----	(ᵃ)	0 00
¼ hour	7.734	110	430				60	60	300	300	----	----
½ hour	8.086	115	430				55	115	300	600	----	----
¾ hour	8.086	115	430				52	167	300	900	----	----
1 hour	7.664	109	388				52	219	300	1,200	----	----
1¼ hours	7.664	109	392				52	271	300	1,500	----	----
1½ hours	7.664	109	408				52	323	300	1,800	----	----
1¾ hours	8.437	120	426				52	375	300	2,100	----	----
2 hours	7.804	111	393				52	427	300	2,400	----	----
2¼ hours	7.945	113	380				52	479	300	2,700	----	----
2½ hours	7.382	105	375				52	531	300	3,000	----	----
2¾ hours	7.593	108	410				52	583	300	3,300	----	----
3 hours	7.664	109	400				52	635	300	3,600	----	----
3¼ hours	8.015	114	370	8.0	10.6	0.0	52	687	300	3,900	----	----
3½ hours	7.804	111	389				52	739	300	4,200	----	----
3¾ hours	8.015	114	400				52	791	300	4,500	----	----
4 hours	8.086	115	380				52	843	300	4,800	----	----
4¼ hours	8.156	116	344				52	895	300	5,100	----	----
4½ hours	7.875	112	402				52	947	300	5,400	----	----
4¾ hours	8.086	115	380				52	999	300	5,700	----	----
5 hours	8.015	114	386				52	1,051	300	6,000	----	----
5¼ hours	7.664	109	372				52	1,103	300	6,300	----	----
5½ hours	7.382	105	390				52	1,155	300	6,600	----	----
5¾ hours	7.523	107	380				52	1,207	300	6,900	----	----
6 hours	8.367	119	384				52	1,259	300	7,200	----	----
6¼ hours	7.664	109	397				52	1,311	300	7,500	----	----
6½ hours	8.015	114	385				52	1,363	300	7,800	----	----
6¾ hours	7.734	110	365				41.3	1,404.8	185	7,985	----	----
6⅚ hours	7.731	110	----	----	----	----	0	1,404.8	0	7,985	----	6 50
Total	228.014	3,243	10,986	----	----	----	1,404.3	----	7,985	----	----	----
Average	7.862	111.8	392.4	----	----	----	51.4	----	292	----	----	----

ᵃ The fire on the grate was not disturbed during the entire run.

TABLE IV.—*Observations in detail of the tests of coals*—Continued.

O.—FIRST TEST OF COAL FROM BETTS' MINE, BATAN ISLAND—66 FIRINGS DURING 4-HOUR TEST.

[Test No. 15, Table II.]

Time after starting.	Steam pressure gauge.		Temperature of flue gases, base of stack.	Average composition of flue gases, in per cent.			Kilos of coal burned—		Kilos of water fed to boiler—		Fire raked or sliced, time after starting.	Cleaned fire, time after starting.
	Kilos per square centimeter.	Pounds per square inch.		CO_2	O_2	CO	During period.	Total.	During period.	Total.		
											h.m.	*h.m.*
Beginning	6.187	88	440	11.4	7.4	0.0	------	------	------	------	------	0 00
¼ hour	5.765	82	465				75	75	275	275	------	------
½ hour	5.765	82	412				75	150	275	550	------	------
¾ hour	5.273	75	403				75	225	275	825	0 45	------
1 hour	5.203	74	540				75	300	275	1,100	------	------
1¼ hours	5.273	75	520	14.2	4.0	0.0	75	375	275	1,375	------	------
1½ hours	5.062	72	480				75	450	275	1,650	------	------
1¾ hours	4.851	69	450				75	525	275	1,925	1 45	------
2 hours	4.008	57	430				75	600	275	2,200	------	------
2¼ hours	3.937	56	425	11.8	6.4	0.2	75	675	275	2,475	------	------
2½ hours	4.078	58	415				75	750	275	2,750	------	------
2¾ hours	4.008	57	405				70	820	275	3,025	2 45	------
3 hours	3.867	55	360				70	890	275	3,300	------	------
3¼ hours	3.656	52	363	7.8	10.0	0.8	70	960	275	3,575	------	------
3½ hours	3.164	45	292				70	1,030	275	3,850	------	------
3¾ hours	2.953	42	250				70	1,100	275	4,125	------	------
4 hours	2.953	42	250				34	1,134	186	4,311	------	4 00
Total	76.003	1,081	6,900	------	------	------	1,134	------	4,311	------	------	------
Average	4.471	63.6	406	------	------	------	70.9	------	269.4	------	------	------

TABLE IV.—*Observations in detail of the tests of coals*—Continued.

P.—SECOND TEST OF COAL FROM BETTS' MINE, BATAN ISLAND—125 FIRINGS DURING 7-HOUR TEST.

[Test No. 16, Table II.]

Time after starting.	Steam pressure gauge.		Temperature of flue gases, base of stack.	Average composition of flue gases, in per cent.			Kilos of coal burned—		Kilos of water fed to boiler—		Fire raked or sliced, time after starting.	Cleaned fire, time after starting.
	Kilos per square centimeter.	Pounds per square inch.		CO_2	O_2	CO	During period.	Total.	During period.	Total.		
											h. m	*h. m.*
Beginning	7.382	105	430	10.9	6.9	0.0						0 00
¼ hour	7.875	112	455				85	85	325	325		
½ hour	6.961	99	455				85	170	325	650		
¾ hour	7.453	106	480				85	255	325	975		
1 hour	7.031	100	460				85	340	325	1,300		
1¼ hours	7.172	102	450				85	425	325	1,625		
1½ hours	6.539	93	440				85	510	335	1,950		
1¾ hours	6.609	94	415				50	560	225	2,175		1 45
2 hours	7.031	100	440				100	660	300	2,475		
2¼ hours	7.593	108	420	10.6	7.4	0.6	85	745	325	2,800		
2½ hours	7.172	102	430				85	830	325	3,125		
2¾ hours	7.172	102	425				85	915	325	3,450		
3 hours	7.382	105	450				85	1,000	325	3,775	2 51	
3¼ hours	7.453	106	430				85	1,085	325	4,100	3 07	
3½ hours	7.664	109	440				85	1,170	325	4,425		
3¾ hours	7.593	108	445				85	1,255	325	4,750	3 34	
4 hours	7.804	111	440				85	1,340	325	5,075		
4¼ hours	7.523	107	400				85	1,425	325	5,400		
4½ hours	7.242	103	365				85	1,510	325	5,725		
4¾ hours	7.664	109	430				85	1,595	325	6,050		
5 hours	7.734	110	405				85	1,680	325	6,375	5 00	
5¼ hours	7.523	107	435	11.0	7.4	0.0	85	1,765	325	6,700	5 14	
5½ hours	7.453	106	430				85	1,850	325	7,025		
5¾ hours	7.945	113	435				85	1,935	325	7,350		
6 hours	7.453	106	450				85	2,020	325	7,675	6 00	
6¼ hours	7.664	109	430				85	2,105	325	8,000		
6½ hours	7.382	105	480				85	2,190	325	8,325	6 23	
6¾ hours	7.523	107	490				85	2,275	325	8,650	6 34	
7 hours	6.890	98	505				38.4	2,313.4	112	8,762		7 00
Total	213.882	3,042	12,760				2,313.4		8,762			
Average	7.375	101.9	440				82.6		313			

TABLE IV.—*Observations in detail of the tests of coals*—Continued.

Q.—FIRST TEST OF COAL FROM THE COMANSI MINE, NEAR DANAO, CEBU—61 FIRINGS DURING 5½-HOUR TEST.

[Test No. 17, Table II.]

Time after starting.	Steam pressure gauge.		Temperature of flue gases, base of stack.	Average composition of flue gases, in per cent.			Kilos of coal burned—		Kilos of water fed to boiler—		Fire raked or sliced, time after starting.	Cleaned fire, time after starting.
	Kilos per square centimeter.	Pounds per square inch.		CO_2	O_2	CO	During period.	Total.	During period.	Total.		
											h. m.	*h. m.*
Beginning	6.961	99	325	9.0	6.5	2.0	57					0 00
¼ hour	7.593	108	385				57	57	290	290		
½ hour	8.015	114	400				57	114	290	580		
¾ hour	7.453	106	385				57	171	290	870		
1 hour	7.312	104	400				57	228	290	1,160		
1¼ hours	7.593	108	495				57	285	290	1,450		
1½ hours	7.242	103	430				57	342	290	1,740		
1¾ hours	7.523	107	390				57	399	290	2,030		
2 hours	7.312	104	385				57	456	290	2,320		
2¼ hours	7.801	111	400	10.0	7.6	0.4	57	513	290	2,610		
2½ hours	7.664	109	455				57	570	290	2,900		
2¾ hours	7.593	108	375				57	627	290	3,190		
3 hours	7.453	106	390				57	684	290	3,480		
3¼ hours	7.172	102	330				57	741	290	3,770		
3½ hours	8.086	115	390				57	798	290	4,060		3 25
3¾ hours	8.015	114	450				57	855	290	4,350		
4 hours	7.382	105	380				57	912	290	4,640		
4¼ hours	7.804	111	360	10.2	5.4	2.0	57	969	290	4,930		
4½ hours	7.453	106	370				57	1,026	290	5,220		
4¾ hours	7.453	106	375				57	1,083	290	5,510		
5 hours	7.664	109	350				57	1,140	290	5,800		
5¼ hours	7.453	106	375				57	1,197	290	6,090		
5½ hours	7.593	108	375				30.4	1,227.4	146.6	6,236.6		5 30
Total	173.593	2,469	8,970				1,227.4		6,236.6			
Average	7.547	107.3	390				55.8		283.4			

TABLE IV.—*Observations in detail of the tests of coals*—Continued.

R.—SECOND TEST OF COAL FROM THE COMANSI MINE, NEAR DANAO, CEBU—68 FIRINGS DURING 7½-HOUR TEST.

[Test No. 18, Table II.]

Time after starting.	Steam pressure gauge.		Temperature of flue gases, base of stack.	Average composition of flue gases, in per cent.			Kilos of coal burned—		Kilos of water fed to boiler—		Fire raked or sliced, time after starting.	Cleaned fire, time after starting.
	Kilos per square centimeter.	Pounds per square inch.		CO₂	O₂	CO	During period.	Total.	During period.	Total.		
											h. m.	*h. m.*
Beginning	7.523	107	325	------	------	(a)	------	------	------	------	------	0 00
¼ hour	7.875	112	355				60	60	260	260	------	------
½ hour	8.086	115	345				60	120	260	520	------	------
¾ hour	7.945	113	330				55	175	260	780	------	------
1 hour	7.453	106	330				55	230	260	1,040	------	------
1¼ hours	7.875	112	360				55	285	260	1,300	------	------
1½ hours	7.593	108	360				55	340	260	1,560	------	------
1¾ hours	8.015	114	330				55	395	260	1,820	------	------
2 hours	7.734	110	355				52	447	260	2,080	------	------
2¼ hours	7.453	106	330				52	499	260	2,340	------	------
2½ hours	8.015	114	315				52	551	260	2,600	------	------
2¾ hours	7.593	108	325				52	603	260	2,860	------	------
3 hours	7.593	108	330				52	655	260	3,120	------	------
3¼ hours	7.382	105	315				52	707	260	3,380	------	------
3½ hours	7.945	113	330				52	759	260	3,640	------	------
3¾ hours	7.453	106	330	------	------	(a)	52	811	260	3,900	------	------
4 hours	7.875	112	495				52	863	260	4,160	------	------
4¼ hours	7.945	113	415				52	915	260	4,420	------	------
4½ hours	7.875	112	325				52	967	260	4,680	------	------
4¾ hours	8.367	119	350				52	1,019	260	4,940	------	------
5 hours	7.945	113	320				52	1,071	260	5,200	------	------
5¼ hours	7.523	107	315				52	1,123	260	5,460	------	------
5½ hours	7.453	106	320				52	1,175	260	5,720	------	------
5¾ hours	7.664	109	315				52	1,227	260	5,980	------	------
6 hours	7.382	105	310				52	1,279	260	6,240	------	------
6¼ hours	7.664	109	345				52	1,331	260	6,500	------	------
6½ hours	7.523	107	330				52	1,383	260	6,760	6 30	------
6¾ hours	7.664	109	350				52	1,435	260	7,020	------	------
7 hours	7.593	108	365				52	1,487	260	7,280	------	------
7¼ hours	7.382	105	365				52	1,539	260	7,540	------	------
7½ hours	7.523	107	327				27	1,566	131½	7,671½	------	7 30
Total	238.911	3,398	10,612	------	------	------	1,566	------	7,671½	------	------	------
Average	7.706	109.6	342	------	------	------	52.2	------	255.7	------	------	------

[a] High.

DISCUSSION.

The data sustain the conclusions that the value of a coal for producing steam in an ordinary boiler is determined not only by its fuel ratio and by the total number of heat units set free during its complete combustion, but it is also dependent largely upon other and variable factors.

Impurities in the coal.—The purity of the coal—that is, the admixture of earthy matter, moisture and other foreign material which it contains—is an important consideration. If the percentage of ash and water is small the theoretical heat value of the coal is proportionally increased and from a commercial standpoint the original cost of freight and handling per thermal unit and the expense of removing the ash as well is correspondingly decreased. These items represent a direct saving. Moreover, with coals high in moisture the efficiency is lowered directly by the specific heat of the water.

The color of the ash indicates the iron content and is also usually taken as an indication as to whether or not the coal will clinker. However, iron is but one constituent and other factors enter in just as they influence the fusion point of clay[12] or cement. As comparatively few coals burn without forming clinker, it is interesting to note that in many of the tests of Philippine coal, in particular the tests of the coal from the military reservation, Batan Island, where the percentage of ash is high and it is brick-red, very little clinker was produced. It is probable that the ash bed in this non-coking, highly volatile coal is not heated sufficiently high to form clinker. The distillation of volatile matter is endothermic and therefore the explanation of the lack of clinker is probably partly to be found in the fact that the distillation of this large percentage of volatile matter keeps the temperature of the fuel bed low. Furthermore, in a non-coking coal the lumps are thoroughly disintegrated with the expulsion of the volatile matter and the ash kept cool by the air and gases passing through and around its particles. If the same ash were in a coking coal it would be held in the lump and probably be heated hot enough on the grate and in the fuel bed to melt it and produce clinker.

It is believed that a reasonable amount of ash has little influence on efficiency other than the amount of combustible carried away, except where it interferes mechanically. If a coal clinkers and tends to close the air spaces it greatly increases the labor in connection with its consumption and entails a loss of heat through the furnace doors through frequent opening to work the fires. On the other hand, although clinker may hinder combustion, it prevents fine coal from falling through the grate and in this way may partially compensate for its inconvenience. The finer and dirtier coal from Batan Island after correcting for loss of fine coal (i. e., calculated to coal actually burned), and the difference in ash content, gave somewhat lower efficiencies than the larger and carefully selected sizes. The only apparent difference in the behavior and quality of the various sizes is that the fine coal, high in ash, tends slightly to smother the fire and steam can not be produced at as great a rate as with the larger sizes. An inspection of Table II shows that the first test of the coal from the military reservation with the highest percentage of ash has a less evaporation per unit of combustible actually consumed than the second and third, which contain less ash, and still less than the fourth and fifth which contain still less ash. The variation, however, is not believed to be due to the ash, but is largely accounted for far more easily by a consideration of the fuel ratio, i. e., $\frac{\text{fixed carbon}}{\text{volatile combustible matter}}$, the greater ratio giving the greater efficiency; although that very high ash may reduce the draft, cause a slower rate of combustion and therefore less complete combustion in the furnace chamber and the range of the water tubes is not without reason.

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[12] Cox, A. J.: The occurrence, composition and radioactivity of the clays from Luzon, P. I., *This Journal, Sec. A.* (1907), 2, 427.

Fire box and grate.—This Bureau has what is ordinarily considered to be a good boiler plant. However, it has a short fire box and only the usual vertical baffling and this is not sufficient to enable it to be run without some black smoke and loss. It is a recognized fact that the loss of heat due to the actual carbon in the escaping gases is small, perhaps never more than 1 per cent, but smoke is a strong indication of the presence of combustible gases the loss of which may amount to several per cent and materially impair the efficiency.

A short fire box is not at all suited successfully to burn Philippine coal. I have often urged[13] the necessity of a setting with an elongated fire box and combustion chamber for burning this class of coal. The combustion space must be long and large enough for the combustible gases and air to mix thoroughly and to produce complete combustion. The United States Geological Survey has expressed the same opinion and further lays special emphasis on the necessity of an additional baffle wall.[14] Such a wall would undoubtedly cause more perfect mixing and therefore more perfect combustion, which is the desired end. It is probable that eddies such as one seeks to attain in a reverberatory furnace, caused by any obstacle in the path of the gases, greatly aid the mixing. Any scheme which works in the direction of retarding the

[13] Cox, A. J.: *This Journal* (1906), 1, 877; *Sec. A.* (1907), 2, 41.

[14] *U. S. G. S. Bull.* (1907), 325, 62.

exit of the gases of the flame stream until combustion of the volatile combustible matter is completed in the combustion chamber, contains the possibility of greatly increasing the efficiency of Philippine coals. Satisfactory baffle walls would probably be of as much value as a considerable increase in the length of the fire box. A boiler with the same setting as those of this Bureau, but arranged with different baffling forming a tile-roof furnace, has been used on Illinois coals and is said to run at capacities of from 50 to 100 per cent without smoke.[15]

Various grates other than the ordinary bar have been suggested and tried on coals of the sub-bituminous variety. It was hoped that the perforated grate would be more economical of coal. However, in the tests of Mr. Betts' coal there was a slight incipient clinker which could not be dislodged from the holes and the steam pressure fell at the end of the test because of lack of draft. It was not possible to experiment much with this coal beforehand and but little information regarding it could be obtained. The grate worked well with Australian coal. With more experience and slight modifications this may still be more satisfactory than the ordinary grates. Mr. Betts has tried a herring-bone grate which he reports to be very successful. The advantage of a grate of this type over the ordinary gridiron is that shorter, thinner and more bars may be used without danger of their melting down and in this way the air spaces increased in number, but diminished in size without changing the ratio between air space and grate surface. It has also been suggested that the loss of combustible matter in the ash could be prevented by burning these coals on a rocking grate. It is hoped that the study of the behavior of Philippine coal and coals of this class will soon result in the discovery of a more satisfactory grate and a method of combustion that will be more economical of the coal.

Reconstruction of the present boiler settings in the Archipelago is out of the question. Greater efficiency, therefore, can be obtained only by building additional baffle walls, using a more satisfactory grate, elongating the fire box or heating the air before entering the grate, and these improvements from an economic standpoint can best be tried in the order of enumeration.

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[15] Breckenridge, L. P.: *Univ. of Ill. Bull.* (1906), **4**, No. 31, 22. M. Ernest Schmidt, *Bull. soc. ind. d'Amiens*, **2–3**, 102; *C. A.* (1908), **2**, 174, has called attention to the fact that it is difficult to destroy smoke after it is once formed, but believes in preventing its formation by gradual introduction of coal into the fire box, if possible under the burning combustible, and finally, by the use of a mass of fire brick kept at a high temperature. He also considers the heating of the air before entering the grate necessary. In the combustion of Philippine coal where high chimney temperatures are obtained this might be accomplished by a down-draft pipe through the stack.

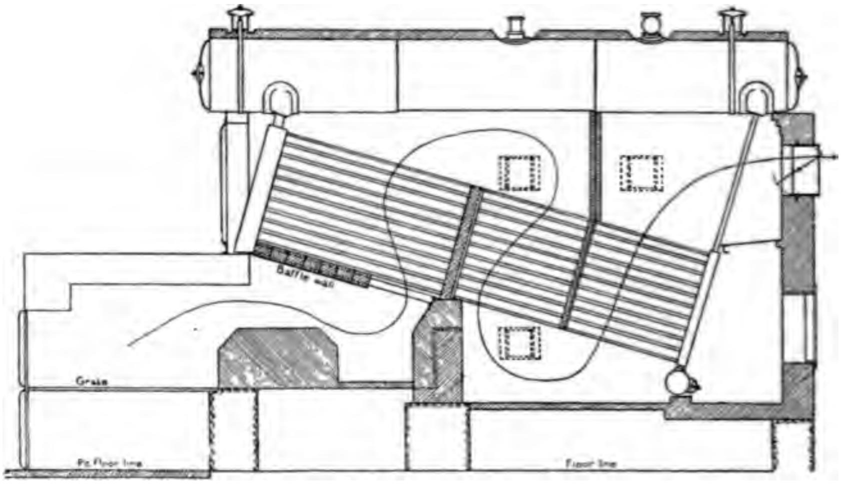

FIG. 2.—IDEAL SECTION SHOWING ADDITIONAL BAFFLE WALL AND AN ELONGATED FIRE BOX.

In the plant of this Bureau, Australian coal burns to a large extent on the grate, while most of the Philippine non-coking coals containing high volatile matter are at a disadvantage, as they burn to a very much greater extent in the combustion chamber. An inspection of the foregoing tests of the coals from Australia (Westwaldsend), Batan Island (Military Reservation and Betts'), and Cebu (Comansi) will show that our boiler-plant is unfavorable to Philippine coal. This may the more readily be seen from the following table:

TABLE V.

Source.	Calorific value of the combustible in calories as determined in a Berthelot-Mahler bomb calorimeter.	Equivalent evaporation of water from and at 100° C. per kilo of combustible actually consumed.	Equivalent evaporation of water from and at 100° C. per kilo of combustible actually consumed, anticipated from the calorific value when Australian coal is taken as the base of comparison.
Australian: (Westwaldsend); average of tests 1, 2, and 3, Table II	7,791	8,688	8,688
Batan Island:			
Military reservation; average of tests 10, 11, 12, 13, and 14, Table II	7,166	6,773	8,000
Betts'; average of tests 15 and 16, Table II	6,297	6,698	7,020
Cebu (Comansi); average of tests 17 and 18, Table II	7,207	7,122	8,040
Poullo; test 19, Table II	7,358		8,210

Coals which burn low and close to the grate give greatest efficiencies; those which burn high lose much through the grate, give low initial temperature in the fire box, leaving the fuel bed comparatively cool, and the result is combustion at the rear of the chamber, imperfect heat absorption and therefore low efficiency. I think this loss is largely due to the type of boiler, and one should be constructed for these coals that would obviate these losses. I should like to be in a position absolutely to name the best class of furnace for each coal, but not enough tests have been carried on to enable me to do so; however, considerable information as to the best form of furnace has been given.

Loss through the grate.—A portion of the combustible matter of the coal falls through the grate into the ash pit and is not burned. For a definite coal this varies with the grate and for a certain grate it varies with the coal. It is a most difficult task, not yet accomplished, to construct a grate that is suitable under any and all conditions of operation. Owing to my inability to have a grate suitable for each coal this discrepancy is much larger in some cases than in others, and therefore I have given, in addition to the usual data, recalculated results to show the values when this factor is eliminated, i.e., as if this amount of coal had never been fired.

Draft, chimney gases and loss through the stack.—Draft, measured by the reduction of pressure as compared with that of the atmosphere, which depends on the relation of boiler, furnace, grate and stack, largely controls the air which enters and the value of the fuel is influenced by it to a marked extent. However, in a boiler plant in the tropics much depends on the direction of the wind, since in most cases the boiler is not protected at the sides. Too much air is better than too little; on the other hand, an excessive amount dilutes the gases, lowers their temperature and increases the waste to the stack by an amount equal to the specific heat of the moisture from the excess of air and the heat carried away by the additional quantity of dry chimney gases. The loss up the chimney decreases and the efficiency rises with a reduction in the supply of air until a point is reached at which the loss due to slightly incomplete combustion is just equal to the gain obtained by decreased loss to the stack. Beyond this point the decrease in efficiency is very rapid. It has been my aim to regulate the air supply as much as possible without reducing the completeness of combustion, and in that way I endeavored to control the quantity of gases leaving the system and therefore the waste heat. Without experience with a given coal it is not always possible accurately to supply the proper amount of air for its ideal combustion. It may be noticed from an examination of the tests that a certain amount of carbon monoxide was observed in the chimney gases. This amount was greatest in those from the coal from the Comansi mine at Danao, Cebu (test 17) where there was an abnormal waste to the stack and the efficiency recorded is therefore probably somewhat low.

It has been shown[16] that any considerable percentage of carbon monoxide is threatening to efficiency. Owing to the infiltration of an unknown quantity of air no exact limit could be set to this, but since the presence of carbon monoxide may also be taken as an indication of other incomplete combustion losses, high carbon monoxide is a prominent danger signal. It has also been shown[17] that the furnace efficiency drops very rapidly after the carbon dioxide content in the flue gases has reached about 9 per cent or perhaps 12 per cent if the gas has not been diluted by leaks. From a knowledge of the law of mass action one would expect, where the oxygen content is low and the carbon dioxide high, that some carbon would only be partially oxidized, that is, the presence of some carbon monoxide would be probable; however, an equilibrium may not always be attained in the combustion chamber. As the flue gases passed the sampler in the seventeenth test the oxygen content was higher and carbon dioxide lower than in the tenth where combustion was complete. Such a condition as that in the seventeenth, where the gas analyses represent the average of a period, might be produced by careless stoking so spasmodic that at times the percentage of oxygen would be small, with incomplete combustion, and at other times so large, that the average oxygen content would be increased. However, I do not believe that this is the case in this series. An explanation which suggests itself is that each individual coal, at any given temperature, may require a certain excess of oxygen, varying with the complexity of the hydrocarbon compounds, to effect complete decomposition of the coal gases. If the latter pass the high temperature of the furnace undecomposed, then the small supply of oxygen is not sufficient to effect combustion before they escape from the combustion chamber.

Furthermore, owing to the coolness of the fuel bed and combustion chamber when highly volatile coals are burned, combustion takes place slowly and it is not surprising that the carbon monoxide and other combustible gases are swept on and cooled below their ignition temperatures before combustion is complete.

The corrected ignition temperatures of various molecular relations of hydrogen and carbon monoxide, with oxygen are the following:[18]

$4H_2+O_2=605°$

$2H_2+O_2=540°$

$H_2+O_2=514°$

$H_2+2O_2=530°$

$H_2+4O_2=571°$

$6CO+O_2=721°$

$4CO+O_2=628°$

$2CO+O_2=601°$

$CO+O_2=631°$

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[16] *U. S. G. S. Bull.* (1907), 325, 65.

[17] *Ibid.* 51.

[18] K. G. Falk. *Ann. d. Phys.* (1907) (4), 24, 450.

The introduction of an inert gas such as the nitrogen content of the combustion chamber, greatly raises the ignition temperature and for the bimolecular reaction between hydrogen and oxygen it is increased according to the equation

$$T = T' + 30\ n$$

where

$$n = \frac{\text{volume of the nitrogen } (N_2)}{\text{volume of the hydrogen } (H_2) \text{ or the oxygen } (O_2)}$$

whichever is present in the smallest quantity. For the trimolecular reaction between carbon monoxide and oxygen the ignition temperature is increased according to the equation $T = T' + 80\ n'$ where

$$n' = \frac{\text{volume of the nitrogen } (N_2)}{\text{volume of the carbon monoxide } (CO).}$$

The temperature coefficient of the reaction velocities for an increase of 10° is 1.31 between the limits 514° and 550° for a mixture of hydrogen and oxygen; and 1.24 between the limits 601° and 645° for a mixture of carbon monoxide and oxygen. The introduction of an indifferent gas (nitrogen) reduces the magnitude of this coefficient in proportion to the quantity added.

For a mixture of two volumes of carbon monoxide and one volume of oxygen Helier[19] gives the following maximum formation of carbon dioxide, expresed in per cent at the given temperature:

Degrees centigrade.	Per cent CO_2	Degrees centigrade.	Per cent CO_2
195	0.13	504	7.3
302	0.44	566	14.43
365	1.41	575	17.27
408	3.03	600	21.14
418	3.41	689	43.36
468	4.64	788	60.3
500	6.2	855	65.0

The formation of carbon dioxide from the carbon compounds in coal or even by burning carbon monoxide itself is no simple one. The dissociation of carbon dioxide into carbon monoxide and oxygen and the part that water plays in the reaction must all be considered. A perfectly dry mixture of carbon monoxide and oxygen can neither be exploded by means of a red glowing platinum spiral nor an induction spark.[20] The particles of water themselves play an important part in the reaction. Even at ordinary temperatures there is a small amount of free hydrogen and free oxygen in water vapor. The equilibrium at 10° contains one volume of free hydrogen and one-half volume of free oxygen for every $4.55 \cdot 10^{23}$ volumes of water vapor. The higher the temperature the greater the amount of uncombined gases in proportion to water vapor. When the equilibrium is reached at 100° there is one volume of free hydrogen and one-half volume of free oxygen for each $1.14 \cdot 10^{17}$ volumes of undissociated water vapor.[21] At very high temperatures free hydrogen and oxygen are present in such quantities that they may be directly determined. These free gases are chemically very much more active than the water molecules themselves. The oxygen unites readily with carbon monoxide to form carbon dioxide or the hydrogen with oxygen to form water or hydrogen peroxide. If the dissociation equilibrium is disturbed in either of these ways, more water molecules dissociate into hydrogen and oxygen atoms. When a temperature of the furnace is reached where this dissociation takes place faster than the dissociation of the oxygen molecules of the air, we have an explanation of the catalytic action of water in the combustion of coal and why a high combustion chamber temperature is desirable.

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[19] *Ann. de Chim.* (1897) (7), **10**, 521; *Chem. Centrbl.* (1897) I, **68**, 487.

[20] Dixon, *Chem. News* (1882), **46**, 151.

[21] Bodländer: *Ahren's Samm. chem. u. chem. tech. Vorträge* (1899), **3**, 388.

In the combustion of a highly bituminous coal, the extent of the loss due to the carbon monoxide and hydrocarbon gases of the gasified coal passing up the stack before combustion is complete may be seen by an examination of the following table:

Element.	Product of combustion.	Heat of combustion in calories.[22]
Carbon	Carbon monoxide	2,435
Do.	Carbon dioxide	8,140
Hydrogen	Water	34,180

It will be observed that each unit of carbon burned only to carbon monoxide will result in a loss of 5,715 calories (over half) and each unit of hydrogen unburned will result in a loss of 34,180 calories. In these experiments this loss has been regulated as well as possible with the dampers and air supply at my disposition, but a difference in construction of the boiler plant would seem advisable for some of the varieties of coal. Approximately perfect combustion can be obtained by proper boiler and furnace design, construction and operation.

An extremely rapid rate of evaporation, a low chimney temperature and completeness of combustion are incompatible. Messrs. Breckenridge, Parr and Dirks[23] found that the maximum rate of evaporation was obtained with the boiler running at its rated capacity, with the flue-gas temperature at about 260° C. With an increase in the rate of combustion the flue-gas temperature increased and the evaporation dropped off. Most of the Philippine coals easily gave a rate of evaporation equal to that obtained with Australian coal on an ordinary run.

Absorption.—Highly bituminous coals are likely to cause a deposit of soot which reduces the efficiency of the heating surface. Boilers must be thoroughly cleaned before beginning tests. The necessity for this precaution is evident in that if the drum and tubes are insulated from the hot gases on the one side by a layer of soot and from the water on the other by a layer of scale, the absorption will be imperfect and the greater this insulation the more resistance to absorption and the greater the loss to the stack by the gases escaping at too high a temperature as compared with that of the steam in the boiler.

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[22] Calculated from the numbers of J. Thomsen: Thermo-chemische Untersuchungen (1882), 2, 52, 283 and 288.

[23] *Univ. of Ill. Bull.* (1906), 3, 39.

Breckenridge *et al*[24] from results of boiler trials made to determine the effect of soot deposits on the evaporation in a horizontal tubular boiler conclude that it is not very marked. They found that the soot burned upon reaching a certain thickness, leaving but a very thin layer. Even with frequent and perfect sweeping of the tubes, no boiler cools the furnace gases to the temperature of the steam, but a certain amount of this heat waste may be recovered and the efficiency somewhat raised by the use of an economizer in the stack.

The effect of scale on the transmission of heat through boiler tubes is very variable, the mechanical structure of the scale being at least as important a factor as the mere thickness. Schmidt and Snodgrass[25] have investigated this effect on locomotive boiler tubes and feel warranted in summing up the results of their tests in the following conclusions:

"1. Considering scale of ordinary thickness, say of thicknesses varying up to one-eighth inch, the loss in heat transmission due to scale may vary in individual cases from insignificant amounts to as much as 10 or 12 per cent.

"2. The loss increases somewhat with the thickness of the scale.

"3. The mechanical structure of the scale is of as much or more importance than the thickness in producing this loss.

"4. Chemical composition, except in so far as it affects the structure of the scale, has no direct influence on its heat transmitting qualities."

Boiler pressure.—The true boiler efficiency is the ratio of the heat absorbed to the heat which is available to the boiler; that is, that portion of the heat in the furnace gases which is above the temperature of the steam. From this it is evident that the higher the working pressure—that is, the higher the steam temperature—the less difference between a fixed temperature of the furnace gas and that of the steam and therefore the less heat available to the boiler. In order to obviate this difference in efficiency I have tried to maintain approximately the same steam pressure in the various tests. In those cases where there is a deviation, the efficiency attained is greater or less than the average accordingly as the steam temperature is greater or less. The facts have not been established giving the exact value of the effect for all changes in steam pressure upon the evaporative efficiency of a boiler. Goss[26] has shown that "changes in steam pressure between the limits 120 pounds and 240 pounds will produce an effect upon the efficiency of the boiler which will be less than 0.5 pounds of water per pound of coal." The difference is not large for the small ranges of pressure common in stationary practice; and although slightly more heat is available and absorbed when a low steam pressure is used, there is a limit below which one can not go, for new losses appear which more than compensate the gain.

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[24] *Loc. cit.*

[25] *Univ. of Ill. Bull.* (1907), 4, No. 15, 1.

[26] High steam pressure in locomotive service (1907), 10. Published by the Carnegie Institute of Washington.

Radiation.—A portion of the heat value is lost by radiation through the fire doors and furnace walls. By the use of a larger furnace and boiler the exothermic loss would be less. More favorable figures than mine have been attained by the Manila Electric Light and Railroad Company for Australian coal of the same source and similar composition as that of tests Nos. 1 and 2, Table II; however, it must be remembered that they operate their steam boilers in large units and that my figures are thoroughly representative of plants of 75-horsepower rating.

Other factors.—There are many other factors which enter into consideration such as the physicial condition of the coal,[27] small experimental errors in its use, personal variables, air leaks which dilute and cool the gases before absorption takes place, relative load carried, moisture from the air and the water of combustion which must be expelled through the stack as superheated steam, etc. Perhaps the greatest of these variables are the fireman and the moisture of the air.

As a rule, the fireman is a cheap laborer secured more for his muscle than his brains, is indifferent to his work and does it in the way that requires the least energy and initiative on his part. A fireman must be intelligent or have constant intelligent supervision to obtain good results. In hand firing, instead of carefully spreading the coal or coking it and then working it back gradually, a stoker will often spread over the fire a tremendous amount of green coal. In this way the flames are smothered, the instantaneous evolution of combustible gases is out of all proportion to the supply of air, they are cooled perhaps below their ignition temperature and thus a large quantity leaves the system unburned. A deep fuel bed is called for in a producer-gas plant, but in steam boiler practice where a complete combustion is desired so that all of the carbon of the fuel will be converted into carbon dioxide a thin fuel bed is needed. When it is noticed that the steam pressure does not respond to the new supply of coal, the fireman with a slice bar or hoe will stir up the new fuel together with that already on the grate, the result being still further loss of coal. Greatly increased evaporation and saving of coal will be obtained by prohibiting these practices. The tendency of most stokers is toward a too frequent use of the bar. If Philippine coal is properly stoked it is not necessary to poke the fire at all. I have made a test of seven hours on this coal without once putting a bar in the fire box.

The great difference in the moisture going into a furnace day by day, largely due to the variation of the daily humidity as well as that between the dry months and the rainy season, had often been noted; but it was left for Mr. Gayley[28] to obtain definite data and show the considerable economy in the working of blast furnaces by reducing the moisture in the air blast to a low and practically constant amount. It is stated as demonstrating this economy that prior to drying the air, throughout a period of eleven days the daily production of iron in the blast furnace was 358 tons with an average consumption of 2,147 pounds of coke per ton of iron, while for a period of sixteen days when the dry-air blast was used the daily production of iron was 447 tons with an average consumption of 1,726 pounds of coke per ton of iron. This shows a credit balance of 20 per cent greater output of iron and 20 per cent reduction in fuel consumed per unit of pig iron and output. However, there are other considerations. Unquestionably the greater output was largely caused by the more perfect maintenance of the regularity of the furnace owing to the practically constant amount of water in the blast. The gases in the former case were composed of 22.3 per cent of carbon monoxide and 13 per cent of carbon dioxide escaping at a temperature of 538° and in the latter of 19.9 per cent of carbon monoxide and 16 per cent of carbon dioxide escaping at a temperature of 376°, so that the economy of fuel is partly traceable to more perfect combustion and less loss through the escape of the gases. However, the fact remains that the saving through the use of dry air and the loss due to the specific heat of the moisture in the use of ordinary air is a great one, and this applies alike to all combustion furnaces.

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[27] There is a marked tendency of the coal from certain parts of the Philippines to fall to pieces. Care must be exercised to prevent the production of a large amount of slack in handling for it reduces the value for steaming purposes.

[28] *Iron and Steel Inst.* (1904), October.

The moisture of the air is a large factor in the tropics, where the atmosphere is of almost unvarying temperature, the thermometer normally standing at 30°, and the humidity is high, the air often being almost completely saturated. The average weight of the water entering the furnace in the above tests was about 5 per cent of the water evaporated in the boiler.

Even when all of these factors are taken into consideration there are sometimes abnormalities in the evaporative efficiency of a boiler which it is hard to explain. Some boilers owing to individual superiority, due to rapidity of water circulation, the use of water that does not foam, etc., are more efficient than others; some furnaces burn all of the volatile matter of a coal while others waste it and even the same furnace behaves differently with different coals.

Theoretically, the volatile matter should be expelled from a coal on the grate and the fixed carbon simultaneously burned, thereby keeping the fuel bed intensely hot. The combustion of the volatile combustible matter should be completed in the combustion chamber. Coals high in fixed carbon burn with a short, hot, smokeless flame and combustion is nearly completed a short distance above the fuel bed, but with highly volatile coals the combustion is incomplete even at the rear of the combustion chamber.

I have already shown[29] that when Philippine coal is rapidly heated in the ordinary laboratory analysis according to the directions recommended by the committee appointed by the American Chemical Society,[30] there is a very large mechanical loss amply indicated by the shower of incandescent carbon particles which are driven off during the first one or two minutes heating. Without the most careful stoking in the furnace there is probably the same rapid expulsion of the volatile matter as in the laboratory method, with a corresponding quantity of fine particles carried mechanically in the gas stream and to a greater or less extent deposited or burned out of the range of the absorption tubes. I have also shown[31] that the presence of water serves to dampen down and hold together the solid particles of a coal, thereby preventing mechanical loss. This is probably where the advantage, if any, comes when an engineer wets a highly volatile coal.

It has been shown[32] that fuels classified according to the increasing percentage of volatile combustible in their total combustible matter, when burned under a Heine boiler decrease somewhat in efficiency. While this conclusion holds when the number of samples averaged is sufficiently large, one must avoid too wide an application of the generalization. Often there are physical features and special reasons for choosing one coal before another when theoretically it is not so good. In coking and non-coking coals and in those entirely different physically, for example, slack and briquettes, clinkering and non-clinkering, there are factors which have many times more weight and such a generalization hardly could be applied to these, while such a comparison is perfectly legitimate and helpful to coals of the same class and physical condition.

It is hoped that as soon as the public realize the availability of reliable information regarding coal, both concerning its composition and steaming value, these means of determining its value may be more often resorted to and that guesswork may be eliminated from the purchase of a coal.

SUMMARY.

The object of this investigation was to determine the steam-making value of the coals of the Philippine Islands as compared with the foreign coals offered on the market in this Archipelago.

All the tests which are described in full were made at the Bureau of Science with a 75-horsepower water-tube Babcock & Wilcox steel boiler over a hand-fired furnace. An average of 111½ per cent of the rated capacity and an average steam pressure of 7.4 kilograms per square centimeter (105 pounds per square inch) was maintained. The average length of the tests was about seven hours. The plant, the apparatus used and all conditions were preserved as nearly constant as possible. It was my purpose to burn each coal with the maximum economy in this type of furnace. For a Philippine coal a regular and uniform method of firing is essential. It was found that the best method of firing was in small quantities every four or five minutes. A thin fuel bed is also needed and it must not be frequently worked. An entire test of seven hours duration was made without once disturbing the fire.

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[29] Cox, A. J.: *This Journal, Sec.* A (1907), 2, 43.

[30] *J. Am. Chem. Soc.* (1899), 21, 1116.

[31] Cox, A. J.: *Loc. cit.* 59.

[32] *U. S. G. S. Bull.* (1907), 325, 89.

Inert matter in a coal is detrimental to its value in that the total number of heat units is proportionally decreased. Moisture further reduces the efficiency directly by the specific heat of the water, but the content of ash ordinarily found in Philippine coal has very little if any further effect. It seldom produces clinker and for this reason the presence of sulphur is no detriment. Moreover the percentage of sulphur in Philippine coal is usually extremely small.

A short fire box, the usual vertical baffling and an ordinary bar grate are not suited successfully to burn Philippine coal. An average of 9½ per cent less of the theoretical heat units were absorbed by the boiler when Philippine coal was consumed in the plant of this Bureau than with the Australian coal ordinarily used and for which the plant was selected and installed. The efficiencies recorded in Table II include those of the boiler, fire box and grate.

There is very little variation in the steam pressure and the amount of water evaporated per hour. When a boiler with a satisfactory rate of water circulation, absorbing surface, etc., has been used the deviation from the maximum efficiency of a plant depends largely on the adaptability of the furnace grate and stack. The economy is greatest with those coals which have a high fuel ratio, burn completely and give a high combustion chamber temperature. With satisfactory absorption the greater the difference between the temperature of the combustion chamber, gases and the boiler, the greater the efficiency and the less the loss to the stack. When Philippine coals are burned in an ordinary furnace they are at a disadvantage as they tend to burn out of the range of the boiler tubes with the result that there is low evaporation and high chimney temperature. A longer fire box or an increased number of baffle walls, or both, and a carefully selected grate would probably greatly increase the efficiency of Philippine coals. If the number of baffle walls is greatly increased, care must be exercised that there is sufficient draft.

The tendency to burn out of the range of the boiler tubes which coals high in volatile matter show, is aggravated by an excessive draft. The greater the quantity of air drawn through the fuel bed, the more rapid the combustion and the farther in the rear of the combustion chamber it takes place. With a heavy draft the result is high chimney temperature and low efficiency. On the other hand, too little air results in low efficiency due to incomplete combustion.

Highly bituminous coals deposit much soot which may reduce the efficiency of the heating surface, and the formation of scale is a factor which needs close attention if maximum efficiency is to be attained. With a change in efficiency other factors of the heat distribution also vary. The radiation is especially variable with the size of the plant and the temperature of the combustion chamber.

The size of the fuel is a very important factor. The crumbling of coal reduces its value for steaming purposes. There is a tendency of coal from some parts of the Philippines to fall to pieces. Care must be exercised in handling to prevent this.

The moisture of the air is a large factor in the tropics. With an evenly warm, almost saturated, atmosphere the amount of water entering the furnace is enormous and considerably lowers the capacity and efficiency of the plant.

The average of the calorific values of all the Philippine coals tested is 6,003 [33] calories and that of the Australian coal [34] purchased by the Government and furnished to this Bureau for fuel is 6,614. In individual cases the calorific value of Philippine coal is as much as that of the Australian coal and in one case showed an efficiency in this plant, which is unfavorable to Philippine coal, within 3.75 per cent as great as that attained when the Australian coal was fired.

With respect to ash, clinker formation and the production of smoke the Philippine coals are superior to any others offered on the Manila market.

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[33] 9/5 calories=B. T. U.

[34] This coal was tested in June, 1907 (tests Nos. 1 and 2, Table II).

ILLUSTRATIONS.

PLATE I. Babcock & Wilcox boilers used in making the tests (cf. p. 304).
II. Voltmeter and ammeter diagrams of tests numbered 1, 2 and 3, Table II (p. 311).
III. Voltmeter and ammeter diagrams of tests numbered 4, 5 and 6, Table II (p. 311).
IV. Voltmeter and ammeter diagrams of tests numbered 7, 8 and 9, Table II (p. 311).
V. Voltmeter and ammeter diagrams of tests numbered 10, 11 and 12, Table II (p. 311).
VI. Voltmeter and ammeter diagrams of tests numbered 13, 14 and 15, Table II (p. 311).
VII. Voltmeter and ammeter diagrams of tests numbered 16, 17 and 18, Table II (p. 311).
VIII. Charts used in judging the color of the smoke (cf. p. 310).
IX. Grating of the charts in Plate VIII drawn to the exact scale.
X. Figure showing graphically the steam-pressure gauge readings of tests numbered 1 to 10, recorded in Table IV, A to J, inclusive. The dotted curves are supplemented from automatic indicator diagrams in order to show the maximum and minimum variations.
XI. Figure showing graphically the steam-pressure gauge readings of tests numbered 11 to 18, recorded in Table IV, K to R, inclusive. The dotted curves are supplemented from automatic indicator diagrams in order to show the maximum and minimum variations.
XII. Figure showing graphically the temperature of the flue gases, base of stack, of tests numbered 1 to 10, recorded in Table IV, A to J, inclusive.
XIII. Figure showing graphically the temperature of the flue gases, base of stack, of tests numbered 11 to 18, recorded in Table IV, K to R, inclusive.

Page.

FIG. 1. (In text.) Showing the flue-gas sampler used in drawing the gases for analysis 308
2. (In text.) An ideal section showing an ordinary type of boiler with an elongated fire box and additional baffle wall........ 344

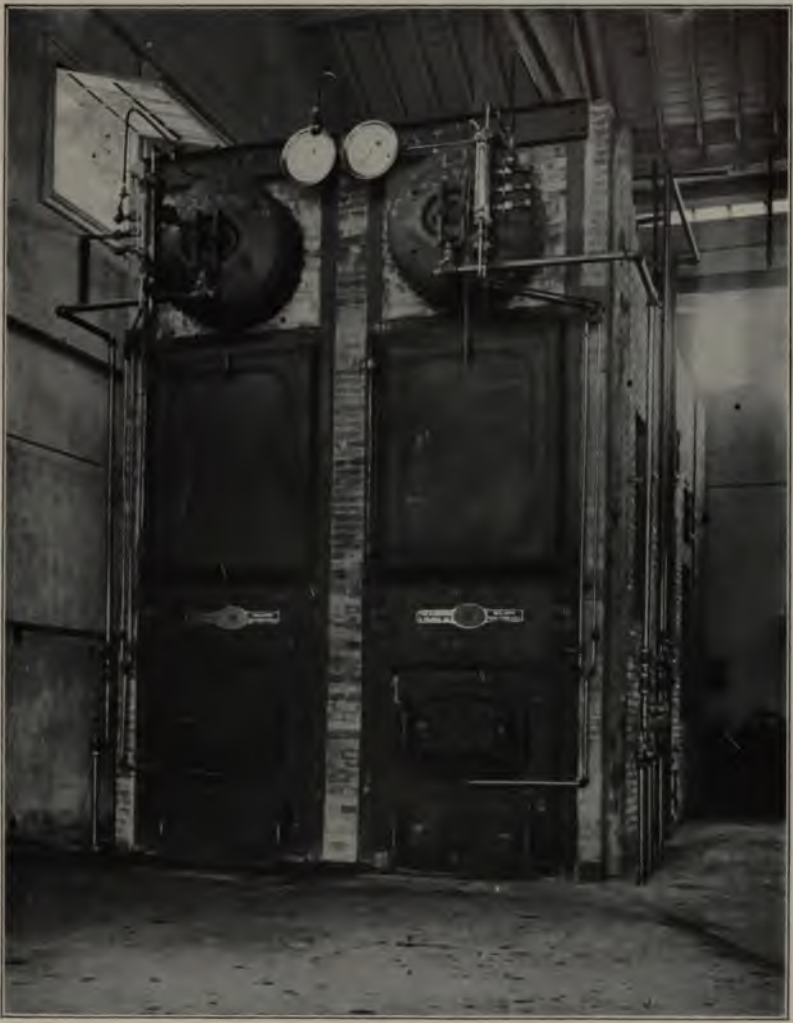

PLATE I.

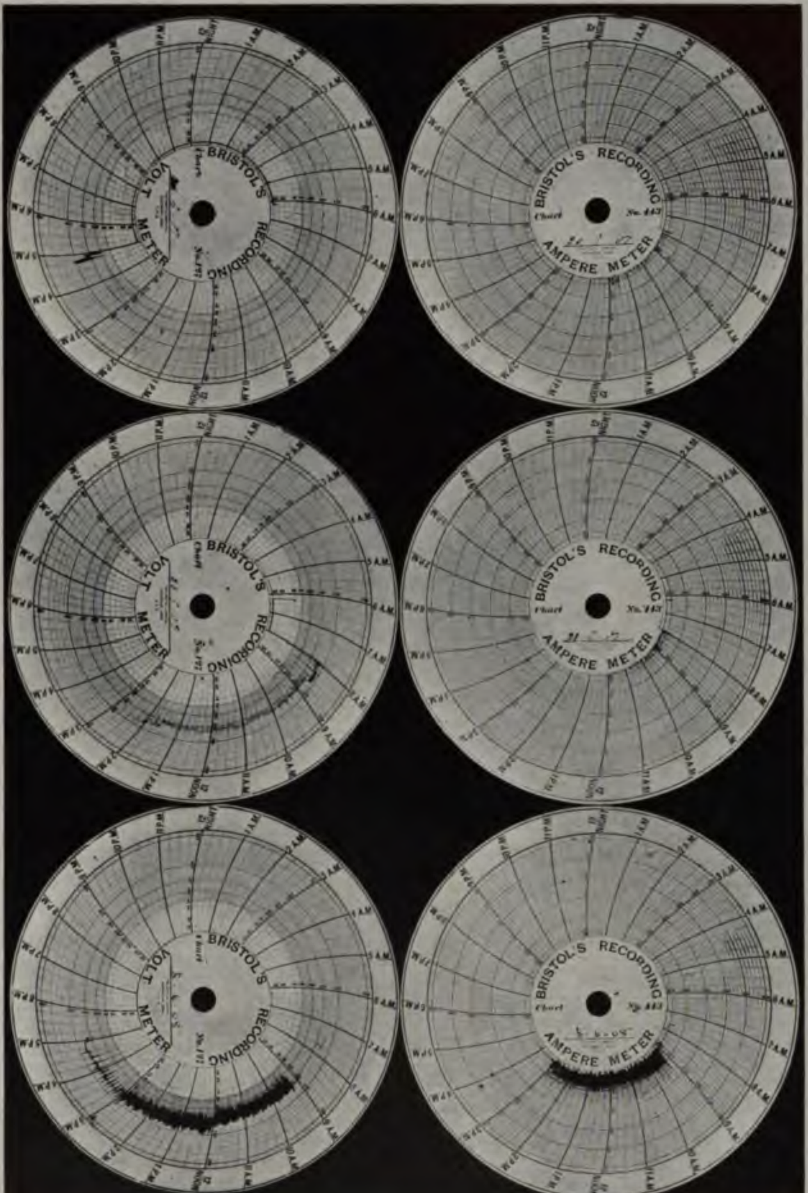
BRISTOL'S RECORDING VOLT METER
Chart No. 172
BRISTOL'S RECORDING AMPERE METER
Chart No. 443
NOON
MIDNIGHT

PLATE II.

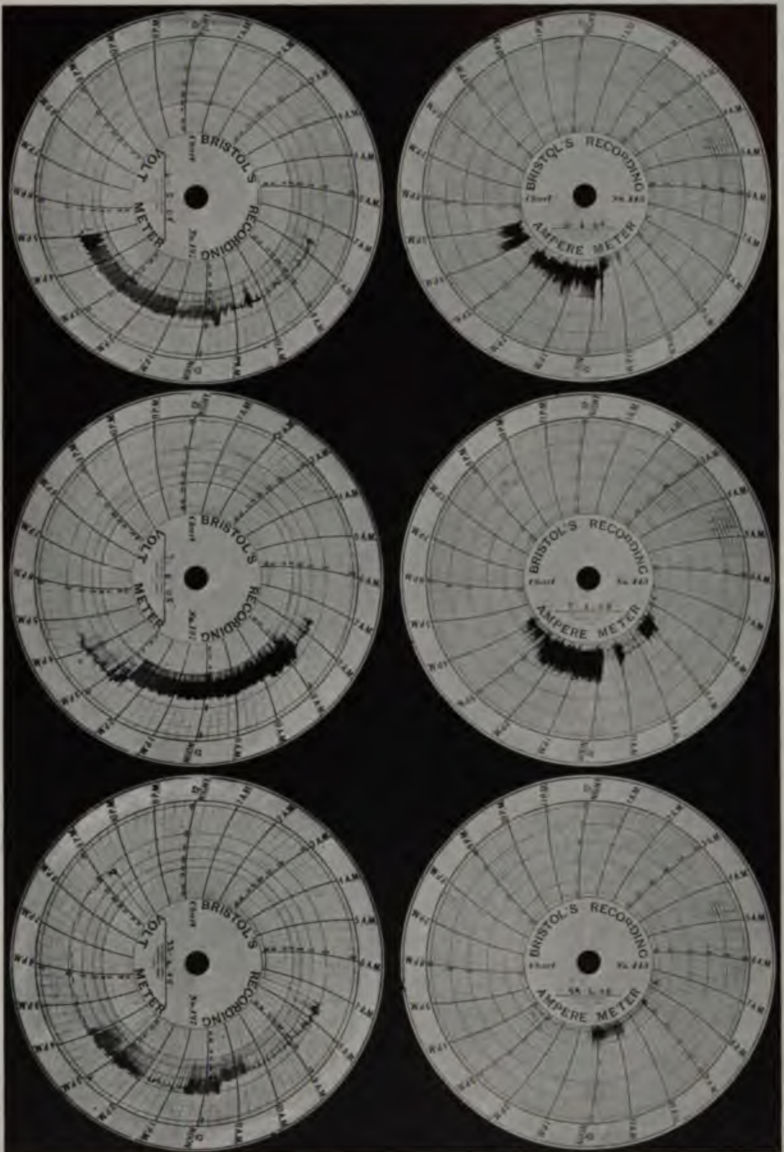
BRISTOL'S RECORDING VOLT METER
BRISTOL'S RECORDING AMPERE METER

PLATE III.

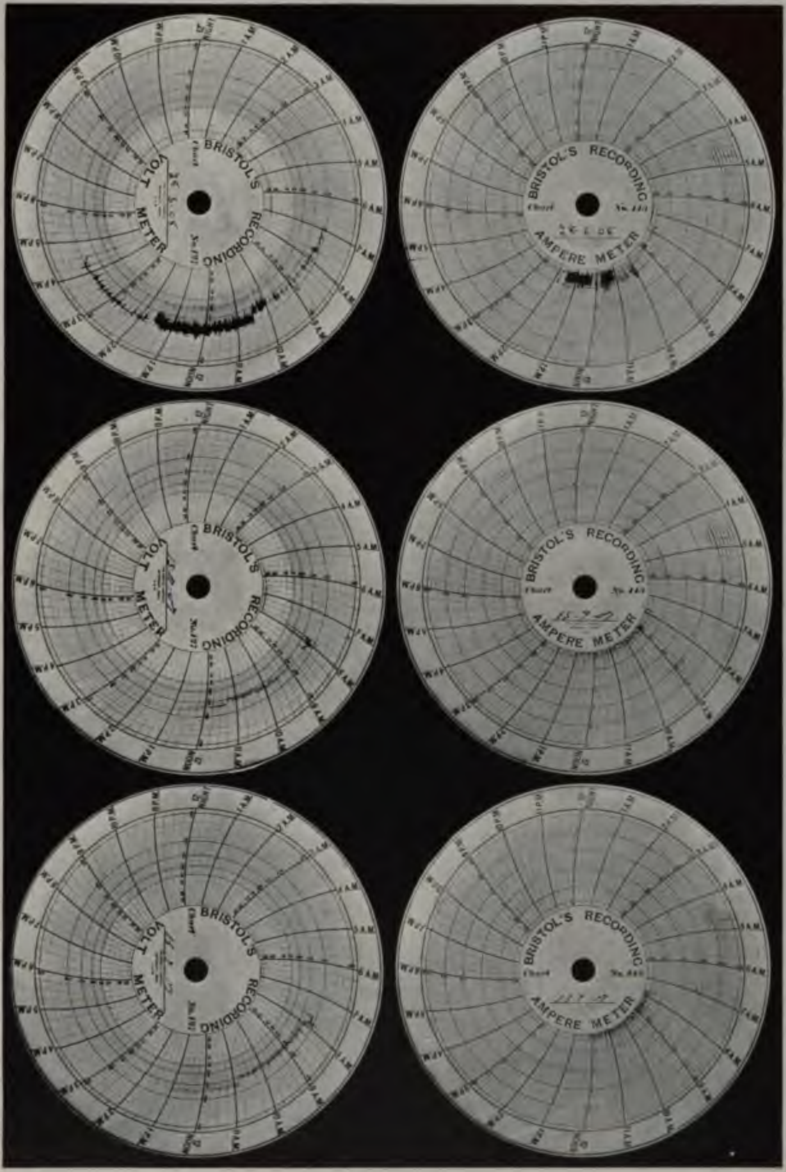

PLATE IV.

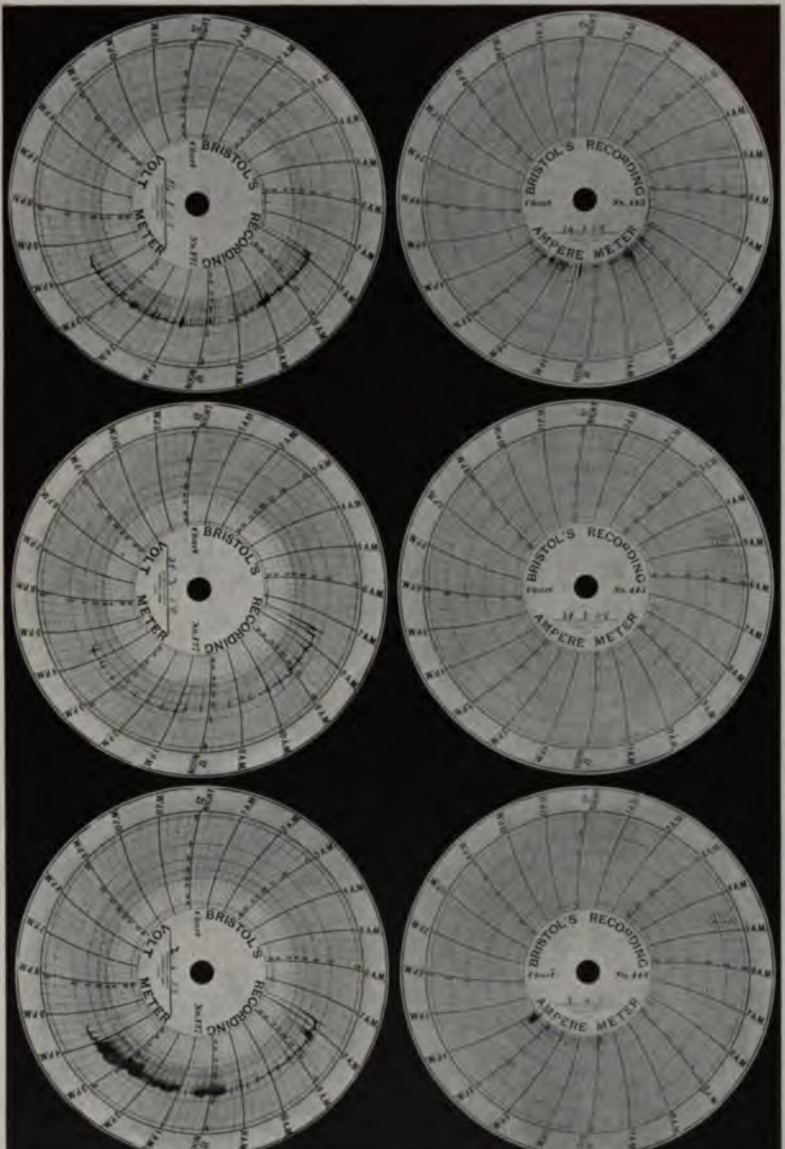
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PLATE V.

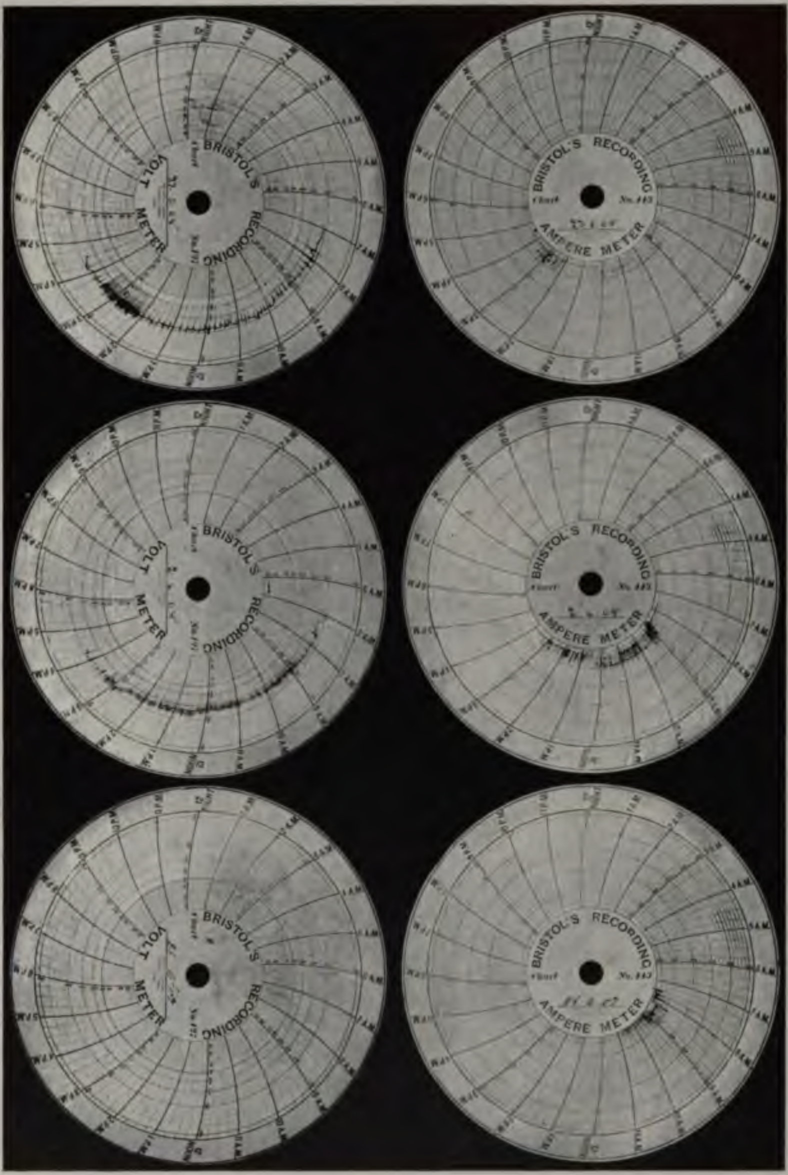
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PLATE VI.

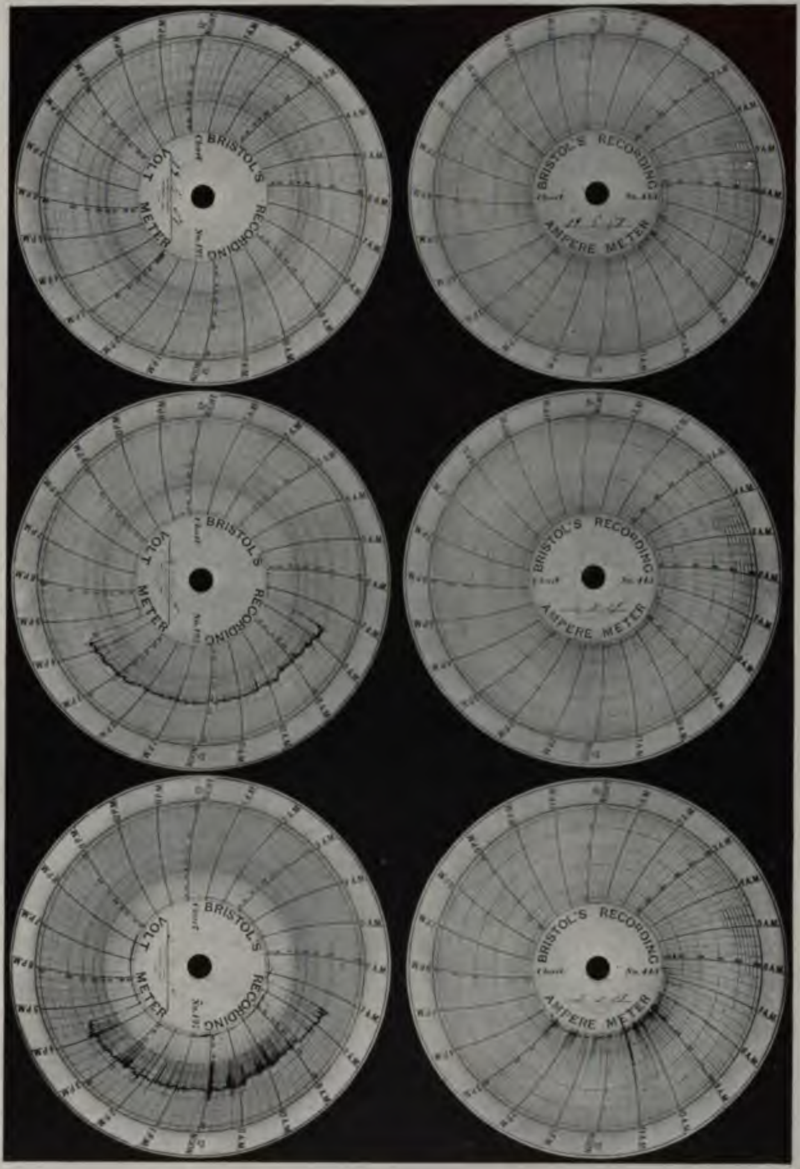
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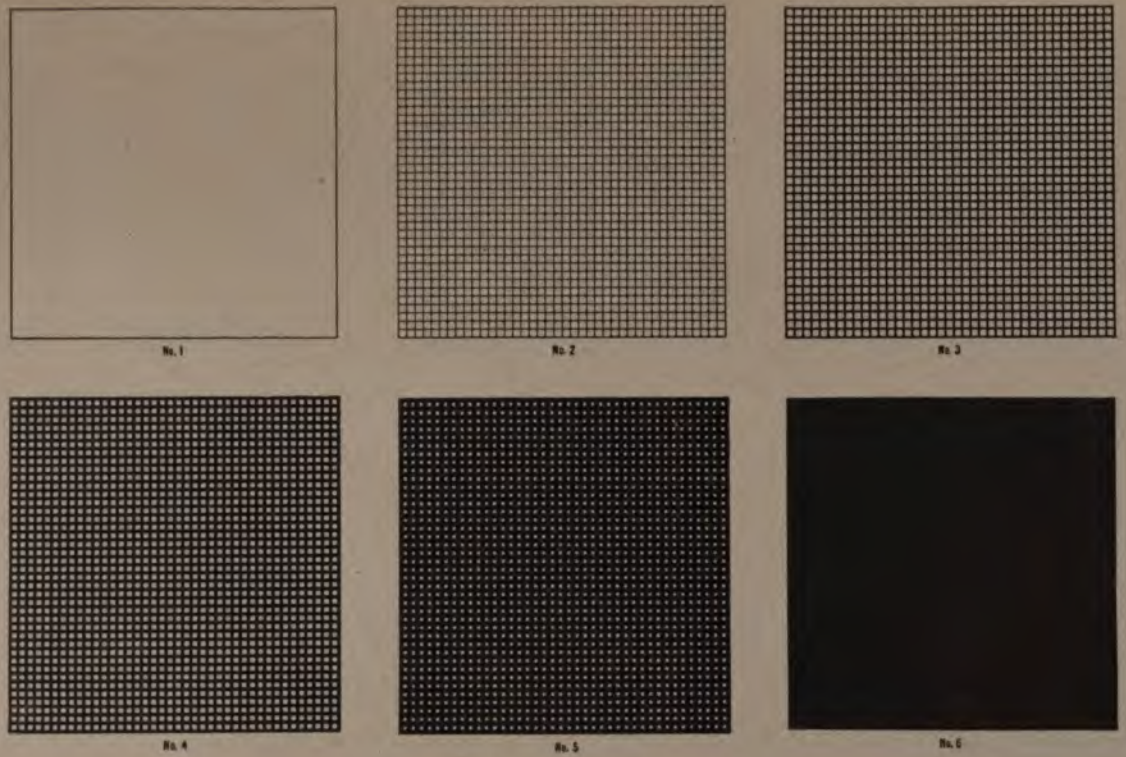
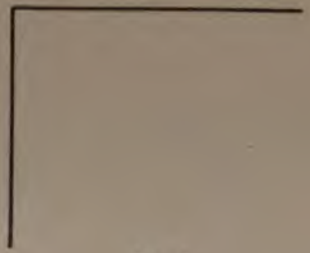
PLATE VII.



No. 1 No. 2 No. 3

No. 4 No. 5 No. 6

PLATE VIII.



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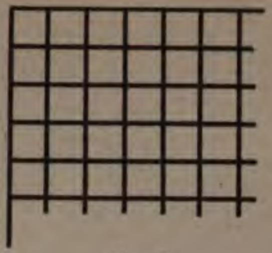

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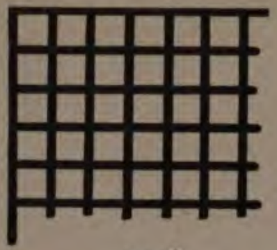

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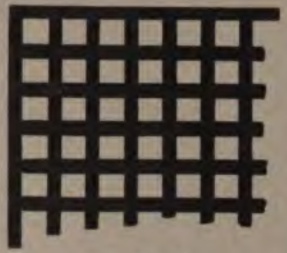

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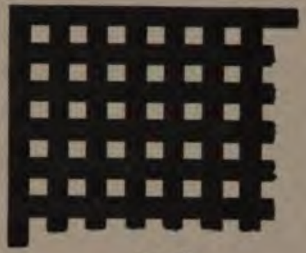

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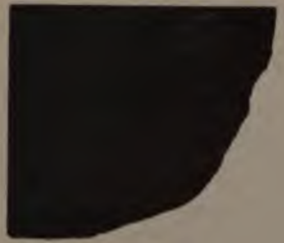

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PLATE IX.

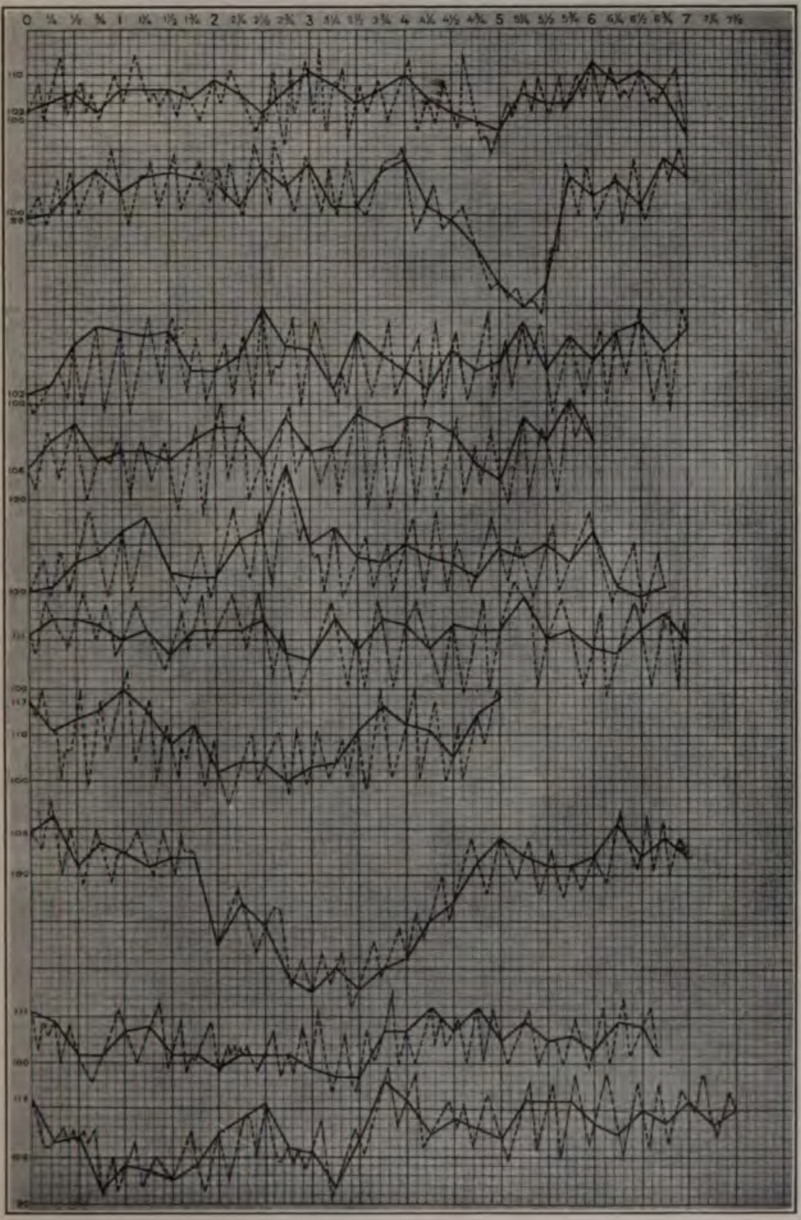
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PLATE X.

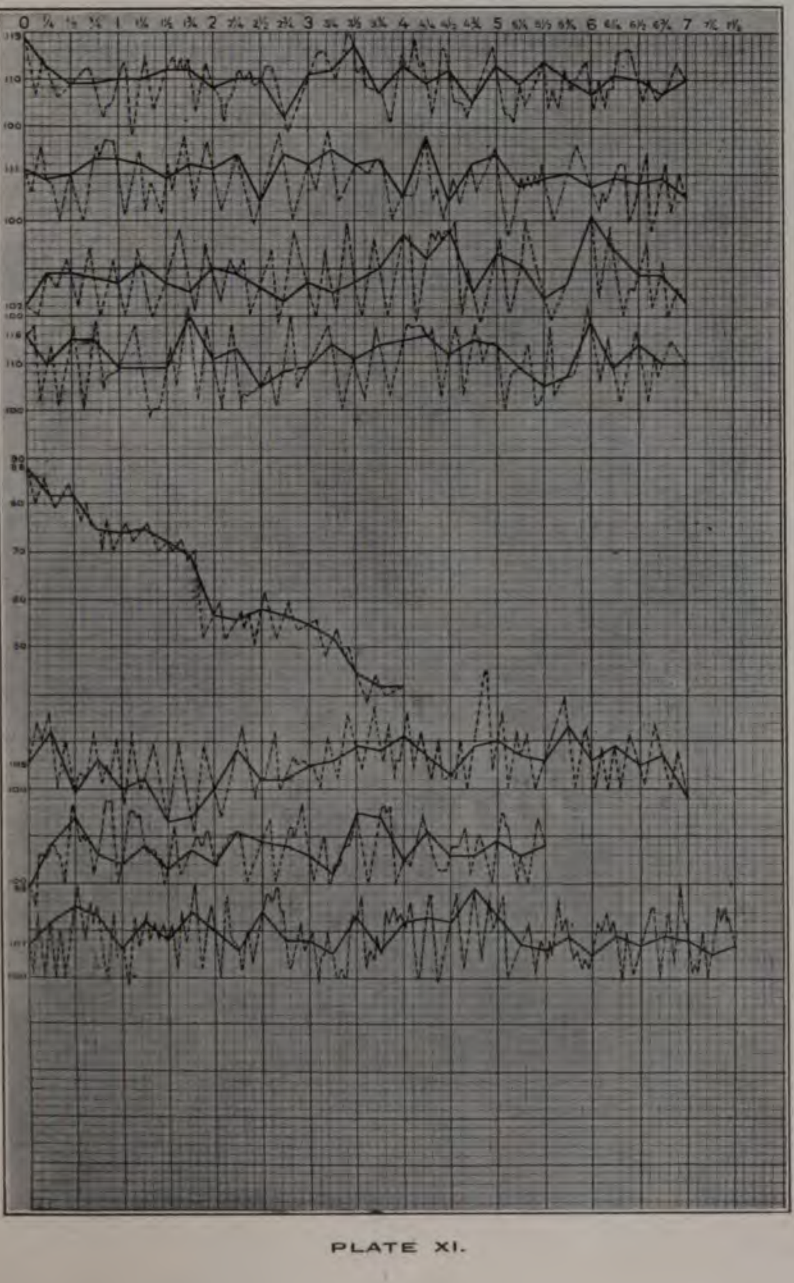
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PLATE XI.

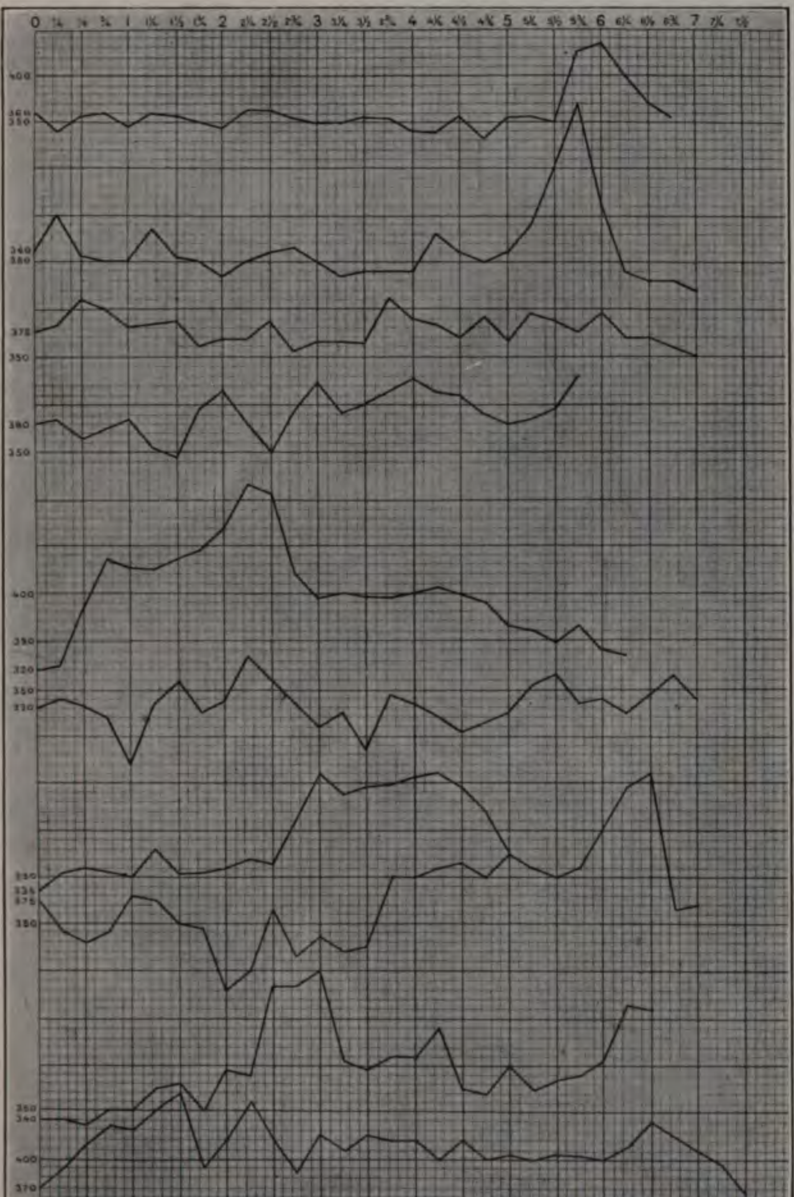
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PLATE XII.

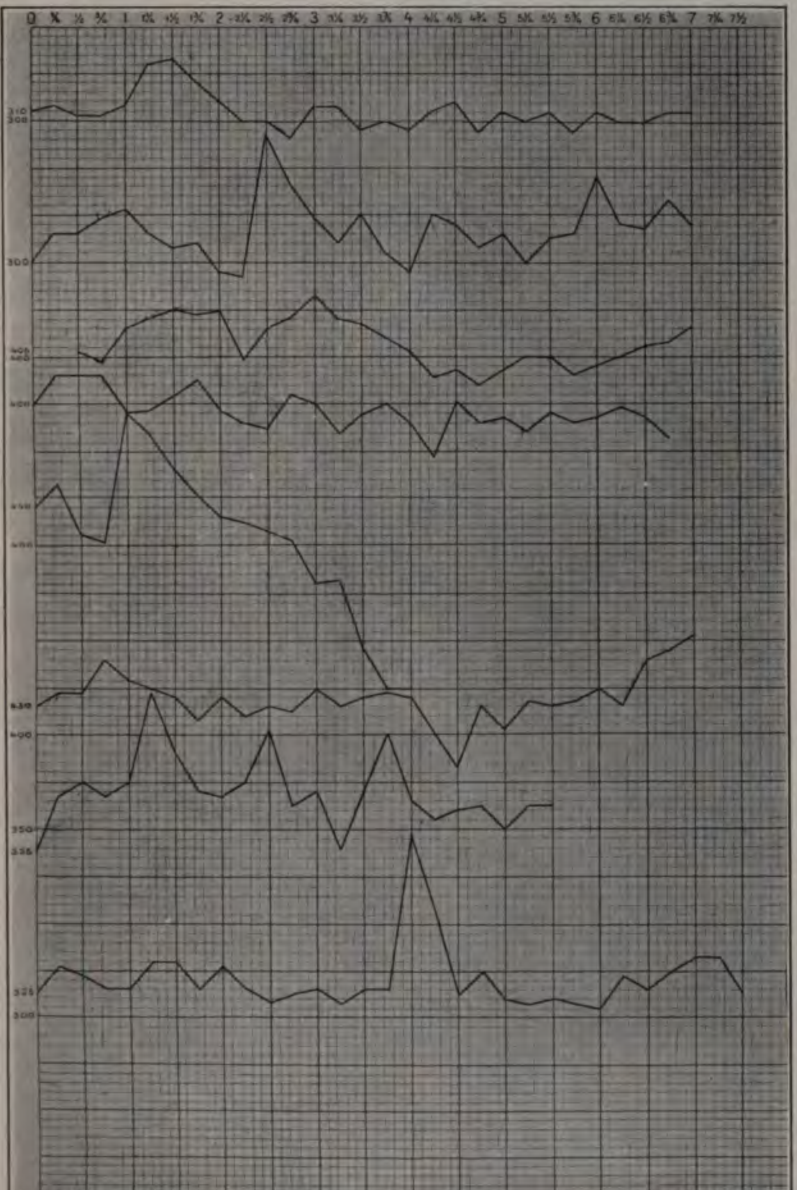
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PLATE XIII.

METHYL SALICYLATE II.[1]—SOLUBILITY IN WATER AT 30°.

By H. D. Gibbs.

(From the Laboratory for the Investigation of Foods and Drugs, Bureau of Science, Manila, P. I.)

In the studies of the hydrolysis of methyl salicylate, the results of which will be published later, it became advisable to determine with some degree of accuracy, the solubility of the ester in water and in some other solutions in which the rate of hydrolysis was being measured.

No accurate measurements have been found in the literature. Cahours[2] records that the oil is scarcely soluble in water. The United States Pharmacopœia[3] and the National Standard Dispensatory[4] say that it is sparingly soluble and the Chemiker-Kalender[5] "wenig löslich;" statements evidently originating from the observations of Cahours made sixty-five years ago.

The method of analysis employed is essentially the same as that described in the first paper. The solution in which the methyl salicylate is to be determined is filtered to remove any undissolved ester (the first few drops passing through the filter being discarded), made strongly alkaline with sodium hydrogen carbonate to unite with and hold back any free salicylic acid, extracted repeatedly, not less than three times, with chloroform and the chloroform extracts run into about 20 cubic centimeters of a 10 per cent solution of sodium hydroxide and saponified in a steam bath. After evaporation of the chloroform the salicylic acid is extracted and made to a definite volume with water for the color comparisons.

When the comparison is made with standard solutions prepared with salicylic acid, the color shades are different, owing to the formation of small quantities of other phenolic compounds besides salicylic acid in the hydrolysis of the ester, and are quite difficult to match in the wedge colorimeter. Some eyes read the percentage very much too low, while others have the opposite tendency. Very satisfactory standards are prepared by dissolving a weighed quantity of pure methyl salicylate in chloroform and carrying through the saponification in the same manner as the determinations. Standards, representing from 1 to 2 milligrams of methyl salicylate in 50 cubic centimeters of solution, have been found to be most satisfactory for comparison with the wedge colorimeter.

---

[1] The first article on the occurrence and determination of salicylic acid in methyl salicylate, the separation and determination of the two substances in foods and drugs, and the hydrolysis of the ester with sodium carbonate and sodium hydroxide appeared in *This Journal, Sec. A.* (1908), **3**, 101, and *J. Am. Chem. Soc.* (1908), **30**, 1465.

[2] *Ann. d. Chem. u. Pharm.* (1843), **48**, 61.

[3] 8th ed. (1900), 290.

[4] (1905), 970.

[5] (1907), **1**, 164.

The solutions for analysis were prepared by agitating a large excess of pure methyl salicylate in water varying in purity from that of the usual laboratory distilled product to a conductivity of 2.8×10^{-6} at 30°.[6] As the rate of hydrolysis of the ester in $\frac{N}{10}$ sulphuric acid is under investigation, the solubility in this strength of acid has been determined from time to time as the hydrolysis proceeds.

In the following tables, No. is the number of the determinations, T is the time expressed in hours during which the solutions were agitated, S is the quantity of substance used in the determination, expressed in cubic centimeters, and Q is the methyl salicylate found in solution and expressed as grams of solute in 100 cubic centimeters of solvent.

TABLE I.—*Solubility of methyl salicylate in water (temperature, 30°).*

No.	T	S	Q
1	18	5	0.063
2	66	10	.069
3	139	10	.076
4	354	10	.076
5	834	10	.071
6	978	5	.074
7	2,160	5	.093
8	386	5	.074

Determinations Nos. 1 to 6, inclusive, were made upon different portions of the same solution, prepared by constantly agitating in a bottle 10 cubic centimeters of methyl salicylate and 500 cubic centimeters distilled water at 30°±1°. No. 7 is the analysis of a mixture of 15 cubic centimeters of distilled water and 0.5 cubic centimeter of methyl salicylate which had been agitated in a sealed glass tube for three months, at temperatures varying from 30° to 100°. The system had approached an equilibrium and the amount of methyl salicylate hydrolized was found to be 0.0125 gram.[7] No. 8 is the analysis of a mixture of 10 cubic centimeters of water, conductivity 2.8×10^{-6} at 30°, and 0.6 cubic centimeter of methyl salicylate which was agitated in a sealed tube at 30°±1°. This determination is probably as reliable as any that have been made and represents a fairly accurate average. Electrodes were sealed into this cell and measurements of the conductivity of the aqueous phase showed that it had changed but little during the last seven days of the ten days' agitation.

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[6] In standardizing cells at 30°, I have used the temperature coefficients found by Jones and West, *Am. Chem. Jour.* (1905), **34**, 381.

[7] This determination is not to be taken as an accurate measure of the equilibrium or the rate of hydrolysis for the reason that the action of the solutions on the glass was found to be considerable. A portion of the salicylic acid was found to be present in the form of the sodium salt.

TABLE II.—*Solubility of methyl salicylate in $\frac{N}{10}$ sulphuric acid solution (temperature, 30°).*

No.	T	S	Q
1	66	10	0.077
2	139	10	.077
3	354	10	.076
4	978	5	.078

It is to be expected that the solvents will show a constantly increasing capacity for dissolving the ester as the hydrolysis proceeds, owing to the slowly increasing concentration of the methyl alcohol, one of the products of the hydrolysis. The rate of the increase in the concentration of the ester is very slow as shown from the tube of distilled water which had been agitated for three months with the solute. The concentration of the methyl salicylate had increased to 0.093, and from the determination of the salicylic acid the concentration of the methyl alcohol in the aqueous solution was found to be approximately 0.02 gram per 100 cubic centimeters. Since the rate of hydrolysis in acid solutions is more rapid than in water, it is probable that the increase in the concentration of the ester will be more rapid in the former than in the latter.

SUMMARY.

The solubilities of methyl salicylate in pure water and in $\frac{N}{10}$ sulphuric acid solution at 30° have been determined. The average of a number of determinations is 0.074 gram per 100 cubic centimeters for the former solvent and 0.077 for the latter.

Slight improvements in the colorimetric method for determining methyl salicylate as given in the first paper are described.

THE COMPOUNDS WHICH CAUSE THE RED COLOR IN PHENOL.

By H. D. Gibbs.
(From the Laboratory for the Investigation of Foods and Drugs, Bureau of Science, Manila, P. I.)

Much investigation and speculation has been indulged in by various writers concerning the cause of the red coloration of phenol. At this time it is well established that impurities in phenol may produce a discoloration. It is also true that pure, colorless phenol is reddened by the action of moisture, air and the more refrangible light rays; in other words by hydrogen peroxide oxidation. The color has been considered to be due to various compounds, but I have found, after investigating the samples which have come under my observation in this laboratory, that the true nature of the colored compounds and the method of their formation is not to be found in the literature.

A brief review of the literature shows the most prevalent idea to be that the coloration is due to impurities. Some of the latest text-books on organic chemistry still cling to this theory.

H. Müller[1] states that phenol will keep well if the impurities are resinified by the action of the air on the alkaline solution during the process of purification.

H. Hager[2] attributes the formation of color to the action of the oxygen and ammonia of the atmosphere, which, in his opinion, probably produce rosalic acid.

A. Sicha[3] says the coloration is due to copper. He prepared phenol which remained colorless for months in the sunlight by distilling in glass vessels. W. Meyke[4] believed the color to be caused by the lead of the containing vessel. P. Ebell[5] states that phenol crystals contain substances which are colored through the action of light. These substances are not metals as is claimed by Meyke.

H. Hager[6] found some samples to be colored by the presence of iron, and he inclines to the view that the red color can not result from a chemical change of the phenol. The basis for the red color does not lie alone in the iron content and may be caused by the raw material or the method of purifying and washing.

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[1] *Dingl. Poly. Journ.* (1866), **179**, 462.
[2] *Chem. Centrbl.* (1880), **11**, 178.
[3] *J. Soc. Chem. Ind.* (1882), **1**, 397.
[4] *Jahresb. f. Chem.* (1883), 875.
[5] *Ber. d. chem. Ges.* (1884), **17**, 69, Ref.
[6] *Chem. Centrbl.* (1885), **16**, 120.

Probably a corallin or tropæolin compound formed by the action of ammonia and ozone of the air prduces the color.

A. Kremel[7] believes that the red color is produced by a large number of metals and metallic oxides, particularly copper, and then lead, silver, and zinc. Tin has no action. He says that these metals enter into combinations, the result being that these compounds dissolve in phenol with a red color. This compound can not be rosolic acid for the reason that it dissolves in concentrated sulphuric acid with a blue color, whereas rosolic acid does so with a yellow color. E. Mylius[8] believes that the glass vessels exercise an influence by giving up alkali when they are easily acted upon by the phenol.

E. Fabini[9] states that the red color is due to the action of hydrogen peroxide in the presence of metallic salts and ammonia. He ascribes the formation of the color to the production of ammonium phenate which is converted into a phenate of the metal present, iron or copper, and which is in turn acted upon by hydrogen peroxide, yielding the red coloring substance which he calls phenerythrene. This compound is soluble in alcohol and phenol, coloring the latter red. It dissolves in sulphuric acid with a blue color.

A. Bidet[10] states that phenol which is carefully purified will remain colorless on exposure to air and light. W. Hanko[11] finds that the coloration is due principally to oxidation. The presence of thiophen, creosol or parakresol does not affect the color. Metals such as copper, iron, and lead and their salts, as well as ammonia and ammonium chloride, accelerate its formation. J. Boes[12] believes it to be highly probable that an isophenol described by Brunner[13] is the cause of the red coloration. Cumaronon is not the cause.

Kohn and Fryer[14] have found that the coloration requires the presence of moisture, air, and light rays, or in the absence of light rays, hydrogen peroxide, and that the presence of metallic impurities accelerates the color formation. They conclude that the colored compound is an oxidation product of phenol and can be formed in pure phenol under the proper conditions of light, moisture, and oxygen. No coloration occurs when the phenol is protected by ruby glass.

A. Richardson[15] has proved the presence of hydrogen peroxide in phenol which has been exposed to the light and he concurs in the opinions of Kohn and Fryer. The light waves at the blue end of the spectrum are the ones which produce the effect and not those at the red.

Kohn[16] repeats that the coloration will take place in pure phenol, when moisture and oxygen are present, under the action of the more refrangible light rays. A. Bach[17] says that while phenol reddens by the action of air, moisture and light the reaction is not as simple as Kohn and Fryer or Richardson believe it to be. He excluded air by working in an atmosphere of carbon dioxide and found that under these conditions the coloration was still produced in the sunlight. He could demonstrate no traces of hydrogen peroxide in the mixture.

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[7] *J. Soc. Chem. Ind.* (1886), **5**, 160.

[8] *Chem. Centrbl.* (1887), **18**, 251.

[9] *J. Soc. Chem. Ind.* (1891), **10**, 453.

[10] *Bull. Soc. Chim.* Paris (1891), III, **5**, 13. *Compt. rend. Acad. d. sc.* Par. (1889), **108**, 521.

[11] *Ber. d. chem. Ges.* (1892), **25**, 386, Ref.

[12] *Chem. Centrbl.* (1902), II, **73**, 50.

[13] *J. pr. Chem.* (1902), **173**, n. s. 65, 304.

[14] *J. Soc. Chem. Ind.* (1893), **12**, 107.

[15] *Ibid.* 415.

[16] *Chem. News* (1893), **68**, 163.

[17] *Chem. Centrbl.* (1894), II, **65**, 318.

J. Walter[18] finds that the presence of iron salts increases the production of the red color. He attributes the coloration to the action of hydrogen peroxide.

L. Reuter[19] has observed that by adding sulphur dioxide to phenol it can be kept colorless for an almost unlimited period. Since the discoloration of phenol does not interfere with its application in medicine he recommends that, to avoid accidents, all phenol be uniformly, artificially colored rather than treated with preserving or decolorizing agents.

EXPERIMENTAL.

The samples of phenol investigated were the purest crystallized products which could be obtained from various manufacturers. In this climate, where the sun's actinic rays are so very intense, they assume a brilliant red color very quickly; it is in fact difficult to preserve the white crystals after a bottle has been opened. Exceptional opportunities are here offered for the study of reactions which are at least in part due to the catalytic action of light rays. The prevailing temperature is 30° and the variations are within rather narrow limits. Many of the reagent bottles standing upon the shelves in a well-lighted laboratory give a distinct reaction for hydrogen peroxide, and whenever tests for hydrogen peroxide are to be made the reagents employed must be purified and tested. Under these conditions appreciable amounts of the reaction products under investigation are produced in the minimum of time.

I have found that quinone, or a quinone derivative is the principal colored compound formed, although during the oxidation of phenol to quinone it is to be expected that other substances will be produced.

Cross, Bevan, and Heiberg,[20] on oxidizing benzol with hydrogen peroxide, found the products to be phenol, catechol, quinol, and quinone. Martinon[21] demonstrated that phenol when oxidized with hydrogen peroxide produced catechol, quinone, and quinol. It is to be expected that the oxidation of phenol will produce the ortho and para derivatives and no meta compounds.[22]

Quinone dissolves in phenol, producing a brilliant red solution. A very small crystal dropped into liquid, colorless phenol reddens immediately upon striking the phenol and is slowly dissolved, producing the characteristic red solution.

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[18] *J. Soc. Chem. Ind.* (1899), **18**, 360.

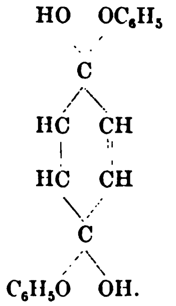
[19] *Ibid* (1905), **24**, 686.

[20] *Ber. d. chem. Ges.* (1900), **33**, 2017.

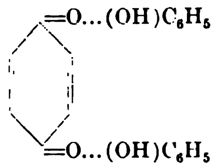
[21] *Bull. Soc. Chim.* Paris (1885), **43**, 155.

[22] Thiele, *Ann. Chem.* (*Liebig*) (1899), **306**, 129.

Quinone and phenol condense readily forming phenoquinone to which Jackson and Oenslager[23] have assigned the formula:



Willstätter and Piccard[24] offer the criticism of this formula that it does not explain the color of the compound or its instability. They suggest the graphic representation:



in which the dotted lines are partial valences. This compound is very unstable. The dilute, aqueous, alcoholic and ligroin solutions are almost colorless and in all probability the condensation product is decomposed on solution in these solvents. On evaporating the solvents the red color gradually makes its appearance as the concentration increases. The aqueous solution reacts in such a way as to show the presence of quinone.

Methods for separating small quantities of quinone from large quantities of phenol have all proved unsatisfactory. In some cases the condensation product, phenoquinone, if not already present will be produced, while in others quinone will be obtained by the breaking down of phenoquinone, if the latter is present. The presence or absence of phenoquinone in the solvent phenol can probably only be proved by physico-chemical methods which have not been adopted in this work.

Samples of colorless phenol to which a few drops of water were added were placed in the sunlight in clear, glass bottles, the liquid half filling the bottle. The samples reddened in a few hours and after four days were so brilliant in color that an analysis was attempted. Other samples which had reddened upon the laboratory shelves upon long standing, were analyzed at the same time.

On pouring small quantities of the red phenol into ten or twenty times the volume of water, an almost colorless solution is formed. The samples which had reddened upon long standing upon the laboratory shelves separated a small quantity of an insoluble, red compound, while those which had been in the sunlight for four days formed a clear solution with no insoluble portion. The red precipitate was collected upon a filter. It was insoluble in water, very slightly so in ligroin and quite soluble in alcohol, forming a red solution. The compound, with the exception of the differences in the solubilities noted, behaves in the same manner as phenoquinone. With alkalies it turns to a blue-green and with concentrated sulphuric acid it forms a brilliant blue-green color. The coloring qualities of the substance are intense. A small amount dissolved in phenol or alcohol produces a brilliant red solution. It is possible that this compound is the ortho modification of phenoquinone. The amounts obtained were so small that no analysis was made.

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[23] *Ber. d. chem. Ges.* (1895), 28, 1614. *Am. Chem. Jour.* (1896), 18, 1.

[24] *Ber. d. chem. Ges.* (1908), 41, 1464.

Reactions for catechol were obtained from the clear solutions, which were almost colorless with a slightly yellow tinge. On addition of lead acetate a copious, white precipitate was formed. After treating this precipitate with sulphurous acid and filtering, catechol was extracted with ether from the filtrate. On evaportion of the ether in a vacuum desiccator, crystals which were proved to be catechol by the ferric chloride and sodium hydrogen carbonate reaction, separated.

On treating 20 cubic centimeters of the phenol which had reddened in the sunlight with a small quantity of sulphurous acid and distilling in steam until all of the phenol had passed over, the residue in the distilling flask was found to contain a very small amount of red precipitate similar to that obtained from the old samples of phenol upon pouring into water. This was collected upon a filter and was found to react with solvents, sodium hydroxide, and concentrated sulphuric acid in the same manner as the red compound separated from other samples. The filtrate, upon extraction with ether, demonstrated that considerable quantities of catechol and quinol were also present.

Quinone was demonstrated by the hydrocoerulignon reaction of Liebermann.[25] The coerulignon employed in this test was made by the method of Hofmann,[26] except that methyl sulphate was substituted for methyl iodide in the production of the dimethyl ether of pyrogallol. It is to be noted that in the presence of considerable quantities of phenol the coerulignon precipitate has a reddish tinge and it does not under these conditions change readily to the steel-blue color which is characteristic of these crystals. Since pure, white crystals of phenol in concentrated, aqueous solution fail to give any coloration whatever, while the red phenol immediately gives a distinct cloudiness which soon becomes red and extends downward throughout the solution, it is fairly safe to assume that the reaction is positive. When the red phenol is dissolved in a very small quantity of water containing just enough potassium hydroxide so that the resulting solution is almost neutral, a copious precipitate of the steel-blue crystals of coerulignon is obtained on adding a drop of the hydrocoerulignon reagent. If the solution becomes too alkaline through the addition of too much caustic alkali it can be made acid with acetic acid before the addition of the Liebermann reagent. An aqueous solution of phenoquinone will also give this reaction for quinone, the coerulignon crystals being very characteristic. This is to be expected from the fact that phenoquinone is a compound of very slight stability.[27]

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[25] *Ibid* (1877), **10**, 1615.

[26] *Ibid.* (1878), **11**, 336.

Hydrogen peroxide has been found to react with hydrocoerulignon, producing the characteristic coerulignon crystals. The samples of red phenol which were found to react with the hydrocoerulignon reagent were tested for hydrogen peroxide and while traces were indicated by both the vanadic acid and the titanic acid reactions, the amounts seem to be too small to account for so great an oxidation of hydrocoerulignon. Any considerable amount of hydrogen peroxide would hardly be expected to be present if it reacts with the phenol to produce oxidation products.

One cubic centimeter of red phenol dissolved in about 15 cubic centimeters of water will liberate iodine from the potassium iodide reagent (potassium iodide dissolved in water with or without the addition of a little ferrous sulphate) as shown by the addition of starch solution. The blue color does not appear at once for the reason that the phenol reacts with the first portions of iodine set free. After some minutes, however, the blue starch compound is unmistakably present.

Another method which is in some respects more satisfactory for producing the reaction, is the addition of 1 cubic centimeter of the red phenol through a pipette reaching to the bottom of a test tube containing the solution of potassium iodide and starch, with or without a trace of ferrous sulphate. Immediately above the red layer will appear the starch-iodine blue. On gently rotating the test tube the blue starch compound will float upward through the colorless reagent. Colorless crystals of phenol will not produce this reaction. While quinone will set iodine free from a solution of potassium iodide its presence is not conclusively proved by this test for the reason that the hydrogen peroxide which may be present will produce the same reaction.

If the theory that the red color is caused by a phenol solution, or condensation of the oxidation products of phenol, principally quinone, is correct, phenol in dilute solutions under the same conditions of moisture, oxygen, and light rays should be oxidized and the solutions should be colored only by these oxidation products. Mixtures of the following proportions were sealed in tubes and agitated in the sunlight at about 30° for seven days.

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[27] Jackson and Oenslager, *loc. cit.*

1. Phenol 1 drop, chloroform 1 cubic centimeter and water 5 cubic centimeters.

2. Phenol 1 drop, chloroform 1 cubic centimeter and $\frac{N}{10}$ sulphuric acid 5 cubic centimeters.

3. Phenol 1 drop, chloroform 1 cubic centimeter and $\frac{N}{10}$ sodium carbonate 5 cubic centimeters.

In each case the tube was half filled with liquid, the remaining space being occupied by air. After a few hours in the sun the chloroform layers in each tube showed a yellow coloration. The aqueous layers in numbers 1 and 2 were colorless, while that in number 3 was slightly yellow. The colors continued to deepen and at the end of one week, when the tubes were opened, the chloroform was a deep yellow and in numbers 1 and 2 contained all the color, while in number 3 the yellow was equally distributed between the two solvents. Quinone was found to be present in every tube. The remaining portions were too small to work with separately; however, a composite mixture of the residues was found to contain catechol. It was to be expected in the tube number 3 that the aqueous layer would also be colored for the reason that quinone in alkaline solutions unites with oxygen to form more complex colored compounds, some of which are soluble in water.

A mixture of 5 grams of phenol, 100 cubic centimeters of chloroform, and 200 cubic centimeters of purified water, which had an electrical conductivity of 3.7×10^{-6}, was agitated in a liter bottle for eight days at a temperature of $30° \pm 1°$. The chloroform became yellow in one day and after eight days was a yellow-brown. On treating portions of the chloroform solution with sulphurous acid and distilling in steam until the phenol was volatilized, the residual solution was found to contain small quantities of quinol and catechol. The aqueous portion of the reaction mixtures shows considerable quantities of hydrogen peroxide by the titanic and vanadic acid tests and by the potassium dichromate and aniline reaction of Bach.[28]

In view of Bach's criticism of the statements of Kohn and Fryer (that the coloration of phenol requires oxygen, moisture and light rays), the experiments of Bach, in which he excluded oxygen by working in an atmosphere of carbon dioxide, were repeated and further extended by the employment of two other gases, hydrogen and nitrogen.

The experiments were carried on in sealed tubes and the necessary precautions were taken to exclude all substances except those the presence of which was desired. The hydrogen employed was generated in a steady, rapid stream by the action of sulphuric acid on pure zinc in a Kipp apparatus. From the generator it was passed through a solution of pyrogallol in caustic potash, concentrated sulphuric acid, tubes of soda lime and calcium chloride, a combustion tube of copper turnings and copper gauze heated to redness and finally a wash bottle of pure, concentrated sulphuric acid, from which it was led directly into the tubes in which the experiments were to be conducted.

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[28] *Compt. rend. Acad. d. sc.*, Par. (1894), 119, 1218.

The nitrogen was obtained by passing atmospheric air through five large wash bottles, each holding several liters of alkaline pyrogallol and then through the same train of apparatus used in purifying the hydrogen. Other indifferent gases of the atmosphere were, of course, present. The carbon dioxide was generated in a Kipp apparatus by the action of hydrochloric acid on marble. It was purified by passing through a calcium chloride tower and a wash bottle of pure concentrated sulphuric acid.

The phenol used was a pure sample beautifully crystallized. The crystals were removed from the bottle by means of platinum tipped forceps and transferred directly to the glass tube through which a rapid current of gas was passing. The form of tube employed and the method of sealing in the required gas so as to exclude all atmospheric air was that employed by Franklin[29] in his work with ammonia with the exceptions that no stopcocks were used on the tubes and at atmospheric temperature the interior of the sealed tubes were at atmospheric pressure.

The following ten tubes and no others comprise this investigation:

I. Phenol (about 2 grams), freshly boiled water 3 drops, sealed in a hydrogen atmosphere.

II. Phenol (about 2 grams), freshly boiled water 1 cubic centimeter, heated to boiling in a hydrogen atmosphere and then sealed.

III. Same as I, except sealed in nitrogen.

IV. Same as II, except sealed in nitrogen.

V. Same as I, except sealed in carbon dioxide.

VI. Same as II, except sealed in carbon dioxide.

VII. Phenol (about 2 grams), water 3 cubic centimeters, boiled in a carbon dioxide atmosphere and sealed.

VIII. Phenol (about 3 grams), boiled in a carbon dioxide atmosphere and sealed.

IX. Same as I, except sealed in atmospheric air.

X. Same as II, except sealed in atmospheric air.

These tubes were then placed in the direct sunlight and constantly agitated by means of a mechanical device.

Tubes IX and X showed a distinct color in a short time and were a light red color in two hours. The color, as nearly as can be judged by the eye, deepened constantly for about ten days. These two tubes are the only ones which show any color visible to the eye. At this writing they have been exposed to the sunlight for fifty-seven days. This work confirms that of Kohn and Fryer.

Since phenol and moisture sealed in this way in an atmosphere of an indifferent gas will form a delicate test for the presence of oxygen, tubes V, VI, and VII produce evidence that carbon dioxide and water do not react with each other in the presence of sunlight to form oxygen or hydrogen peroxide and other products according to the von Baeyer assimilation hypothesis. Bach,[30] however, states that he has produced this decomposition in the presence of uranium acetate by passing the gas into a solution of the salt in the sunlight, obtaining formaldehyde and hydrogen peroxide as the products. Euhler[31] severely questions these results. The decomposition of carbon dioxide in the presence of water has been effected by Löb[32] by means of the silent electric discharge, the products being carbon monoxide, oxygen, hydrogen peroxide, formic acid, and formaldehyde. It would thus appear that the reaction between carbon dioxide and water requires the presence of a more powerful catalytic agent than sunlight. From the work of Kastle[33] and others, it is evident that the presence of phenol, a peroxidase accelerator, would have a beneficial effect upon such a reaction when once it is started.

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[29] J. Am. Chem. Soc. (1905), 27, 831.

CRITICISMS OF SOME OF THE EARLIER WORK.

While it may be possible that some of the impurities in phenol such as ammonia, thiophene, creosol, parakresol, etc., may cause a discoloration as stated by Müller, Sicha, Meyke, Ebell, Hager, Kremel, Mylius, Fabini, and Bidet; impurities, other than moisture and oxygen, do not cause the coloration of pure phenol. The oxygen of the atmosphere was thought by Hager and Ebell to produce the red color through its effect upon the impurities present and not upon the phenol itself. Fabini, while he ascribes the action to hydrogen peroxide, also considers that impurities such as metallic salts and ammonia must be present.

Although Kohn and Fryer, and later Richardson, proved the cause of the coloration to be hydrogen peroxide, the explanation of the mechanism of the reactions involved is not entered into by them, except that the former hint at the possibility of an indophenol being present. The experimental proof upon which Bach bases his criticism of the work of Kohn and Fryer must be inaccurate. When he attempted to exclude oxygen by working in an atmosphere of carbon dioxide it is highly probable that he did not rigidly accomplish the desired result, or else other impurities were present.

Because Bach failed to find hydrogen peroxide in the mixture of phenol, water, and carbon dioxide it can not be considered proved that available oxygen was not present to react with the phenol. It is very improbable that rosolic acid, corallin, or tropæolin as suggested by Hager have produced the color in the samples of phenol investigated by him.

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[30] *Ber. d. chem. Ges.* (1894), **27**, 340.

[31] *Ibid.* (1904), **37**, 3414. Bach's answer, *Ibid* (1904), **37**, 3985; (1906), **39**, 1672.

[32] *Ztschr. f. elek. Chem.* (1906), **12**, 282.

[33] *Am. chem. Jour.* (1908), **40**, 251.

The phenerythrene of Fabini may well be phenoquinone or a derivative of quinone. The existence of the isophenol of Brunner, to which Boes ascribes the color, is problematical.

Since quinone, produced by the oxidation of phenol, has been found to produce the major portion of the color in the samples examined by me, it is evident that sulphur dioxide as suggested by Reuter, and stannous salts as mentioned by Kremel will retard the production of the colored compounds, while many other metallic salts, as stated by Sicha, Meyke, Hager, Kremel, Mylius, Fabini, Kohn and Fryer, and Walter will accelerate this phenomenon by reason of their tendency to increase the rate of oxidation.

SUMMARY.

The tendency which phenol has to assume a red color on standing has generally been attributed to impurities. While several workers have proved that pure phenol is colored in the presence of moisture, oxygen, and light rays or by hydrogen peroxide oxidation, no explanations of the reactions involved have been made. This work has proved the principal products to be quinone and catechol. The major portion of the color in red phenol is produced by quinone or quinone derivatives in solution. The presence of the brilliant red condensation product, phenoquinone, is highly probable.

ON THE DETECTION AND DETERMINATION OF COCONUT OIL.[1]

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Hodgson[2] describes what purports to be an accurate method for the detection and estimation of coconut oil when used as an adulterant of butter. He states that he has found "the quantity of oxygen required to oxidize a given quantity of the saponified fat, is, in the case of butter fat, invariable."[3] In the case of coconut oil he finds the quantity of oxygen required to vary considerably in the twenty samples[4] examined, but the largest amount required by any of the samples is much less than that used by an equal amount of butter fat.[5] Hodgson maintains that the composition of mixtures of coconut oil and butter fat has been accurately determined[6] from this constant.

The method employed consists in the oxidation of 20 cubic centimeters of a 0.1 per cent aqueous solution of the saponified fat with $\frac{N}{10}$ potassium permanganate solution. The oxidation is carried on at the temperature of 100° in the presence of a large excess of sulphuric acid and potassium permanganate. The proportions are 20 cubic centimeters of a 0.1 per cent solution of the products of saponification, 50 cubic centimeters of $\frac{N}{10}$ potassium permanganate and 50 cubic centimeters of a 50 per cent solution of sulphuric acid. This mixture is heated for thirty minutes at a temperature of 100° and the excess of potassium permanganate titrated with $\frac{N}{10}$ oxalic acid or ferrous ammonium sulphate. Results of remarkable uniformity were obtained with various mixtures of butter and coconut oil.

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[1] Since the completion of this paper a number of investigators have found Hodgson's method to be valueless. For the reason that no one has pointed out the real cause for its failure we are perhaps justified in publishing our results, even though we are again proving the fallacy of the method. We have been for some time experimenting upon coconut oil and our investigations in other directions than those chronicled here are being continued.

[2] *Chem. News* (1907), **96**, 273, 288, and 297.

[3] *Ibid*, 273.

[4] Obtained in Birmingham, England.

[5] *Ibid.*, 288.

[6] *Ibid*, 297.

In the hands of the writers this method has not only failed as a quantitative method for the estimation of coconut oil, but it has also failed to show any marked differences, which can be depended upon, between a number of different fats. The reason is easily found.

The permanganic acid which is formed upon acidification of a potassium permanganate solution is readily decomposed on exposure to light or on gentle heating, with the separation of oxides of manganese and loss of oxygen. On boiling the evolution of oxygen is more rapid.[7] Even a weak solution of permanganic acid continually evolves oxygen. Dammer[8] states that in the presence of an excess of sulphuric acid permanganic acid is reduced.

Morse, Hopkins, and Walker[9] have found that permanganic acid and potassium permanganate are reduced by precipitated superoxide of manganese with the liberation of three-fifths of the active oxygen and that solutions of potassium permanganate are more stable if freed from suspended oxide and kept in darkness or diffused light. Even pure solutions are decomposed in direct sunlight. Morse and Reese[10] state that they have "always found dilute, moderately acidified solutions of permanganate quite stable at ordinary temperatures, provided they were free from oxide," and that the decomposition of permanganic acid by the peroxide, attended by the liberation of oxygen, is a continuous reaction, which ceases only when all of the acid has been reduced to the oxide.

These references seem to have escaped the attention of Mr. Hodgson. He mentions no precautions which were taken to purify his permanganate solutions, does not speak of any decomposition of the permanganate and altogether has no difficulty in obtaining results, which in view of our knowledge of the behavior of permanganate solutions, are without sufficient experimental foundation.

Ross and Race[11] have found Hodgson's method to be "unworkable." Their experiments have shown them that "sulphuric acid of the strength prescribed exerts under the conditions laid down a considerable action on potassium permanganate" and that "owing to the retention of the hydrated oxides of manganese by the insoluble fatty acids liberated on the addition of acid" difficulty was experienced in obtaining a good end point. Thompson and Tankard[12] have found that the permanganate solution is attacked by the reagents used and pronounce the process "fundamentally unscientific and based upon error."

When the method of oxidation of the saponified fats is carried out according to the described method, the loss of active oxygen of the permanganate solution varies little in the case of each of the fats and oils with which we have experimented and moreover this loss in active oxygen is about the same as when distilled water is used instead of the soap solutions. In one case the lost oxygen escapes into the atmosphere.

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[7] Roscoe and Schorlemmer: Treatise on Chemistry (1900), **2**, 919.

[8] Handbuch der anorganischen Chemie (1893), **3**, 251.

[9] *Am. Chem. Jour.* (1896), **18**, 401.

[10] *Am. Chem. Jour.* (1898), **20**, 526.

[11] *Chem. News* (1908), **97**, 110.

[12] *Chem. News* (1908), **97**, 146.

in the other it has some action upon the oxidizable organic matter present. The results recorded in the following table were obtained under uniform conditions and with permanganate solutions which were especially purified. All suspended oxides were removed by drawing the solution through a tightly packed asbestos filter 10 centimeters thick. A layer of oxides of manganese was visible on the top of the asbestos and at no point was the visible penetration greater than 1 millimeter.

Table I.—*Oxidation of fats with potassium permanganate solution.*

Laboratory No.	Samples.	Cc. of $\frac{N}{10}$ permanganate used.	Oxygen[13] equivalent.	Laboratory No.	Samples.	Cc. of $\frac{N}{10}$ permanganate used.	Oxygen[13] equivalent.
55157	Butter	38.5	154.0	49019	Lard	37.6	150.4
55157	do	38.5	154.0	14	do	37.8	149.6
23	do	37.7	150.8	14	do	36.5	146.0
23	do	37.6	150.4	14	do	37.3	149.2
22	do	38.4	153.6	2	do	39.7	158.8
22	do	38.4	153.6	2	do	39.8	159.2
25	Cacao butter	37.7	150.8	2	do	38.9	155.6
25	do	37.7	150.8	2	do	38.9	155.6
16	Coconut oil (rancid)	40.3	161.2	4	Olive oil	36.2	144.8
16	do.	40.3	161.2	4	do	37.6	150.4
16	do	40.3	161.2	3	do	37.7	150.8
56109	Coconut oil (refined)	40.1	160.4	3	do	37.5	150.0
56109	do	40.1	160.4	3	do	37.5	150.0
32	Coconut oil	38.3	153.2	3	do	37.5	150.0
32	do	38.3	153.2	31	Linseed oil	37.2	148.8
33	do	39.3	157.2	31	do	37.2	148.8
33	do	39.3	157.2	28	Pili-nut oil	37.3	149.2
34	do	38.9	155.6	28	do	37.3	149.2
34	do	38.9	155.6	17	Oleic acid	35.5	142.0
6	do	40.6	162.4	17	do	35.5	142.0
6	do	40.5	162.0	18	Palmitic acid	39.6	158.4
27	Castor oil	36.3	145.2	18	do	39.6	158.4
27	do	36.3	145.2	19	Stearic acid	36.2	144.8
20	Imitation butter	39.0	156.0	19	do	36.2	144.8
20	do	39.1	156.4	29	Glycerol	36.2	144.8
53280	Lard	42.2	168.6	29	do	36.2	144.8
53280	do	42.2	168.8		Distilled water	38.3	153.2
49019	do	37.6	150.4		do.[14]	38.6	154.4

The various fats and oils require different amounts of oxygen for their complete oxidation to carbon dioxide and water. The glycerol esters of four of the most commonly occurring fatty acids and glycerol itself would have theoretically the following oxygen numbers.

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[13] The so-called oxygen equivalent is the grams of oxygen times 100 required for 1 gram of fat.

[14] Different solutions of especially purified potassium permanganate were used to titrate some of the duplicates. Many other determinations, uniform with these and not recorded here, were made.

TABLE II.

Fat.	Oxygen equivalent.
Butyrin	196.7
Palmitin	287.8
Olein	289.6
Stearin	293.0
Glycerol	121.6

The oxidation as carried out by the previously described method does not go this far. If the 0.1 per cent solution of the products of the saponification are oxidized with $\frac{N}{10}$ potassium permanganate by the usual method of titration, the oxidation stops far short of complete production of carbon dioxide and water. A number of fats were treated by the following method:

To 25 cubic centimeters of the 0.1 per cent solution after saponification, were added 25 cubic centimeters of 50 per cent sulphuric acid solution. The mixture was kept at the boiling temperature and $\frac{N}{10}$ potassium permanganate added gradually, until the pink color remained permanent for three minutes. The evaporated water was replaced from time to time. An excess of permanganate was always indicated by a small quantity of suspended particles of the oxides of manganese.

Fairly concordant results were obtained. In the following table the averages of a number of determinations, and for comparison the iodine numbers, are given.

TABLE III.

No.	Sample.	Permanganate, cc. $\frac{N}{10}$.	Oxygen equivalent.	Iodine[16] numbers (Hanus).
6	Refined coconut oil	7.8	24.96	8.-9.5
32	Coconut oil	7.5	24.00	
55157	Butter	12.4	39.68	26.-38
54452	do	11.7	37.44	
25	Cacao butter	12.8	40.96	32.-41
28	Pili-nut oil	15.0	48.00	59.8
13	Lard	15.6	49.92	62.6
2	do	15.4	49.28	67.4
27	Castor oil	21.8	69.76	83.-85
3	Olive oil	24.4	78.08	79.-88
31	Linseed oil	29.9	95.78	173.-180
29	Glycerol	28.0	89.6	

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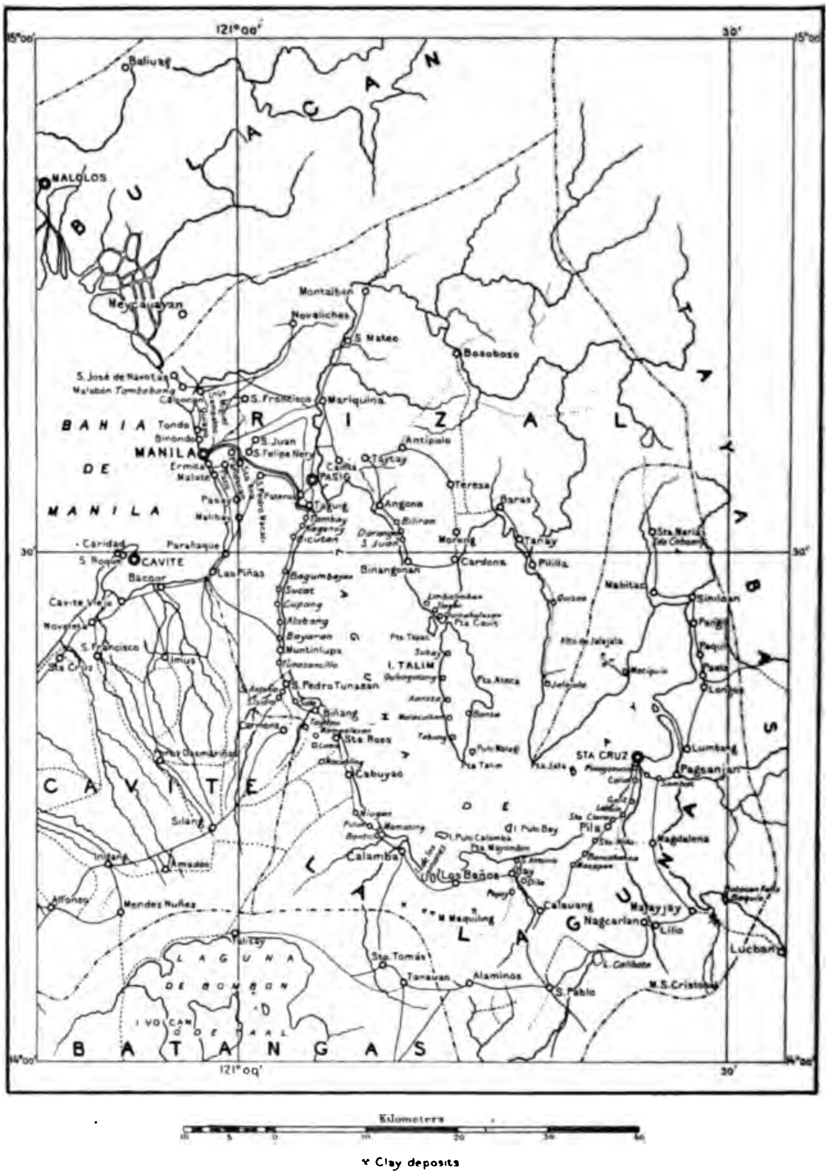
[16] The iodine numbers are taken from Lewkowitsch, "Oils, Fats, and Waxes," and from Leach, "Food Inspection and Analysis," except the pili-nut oil and the lards which are our own determinations.

It is readily seen that these results bear no relation to the amount of oxygen which would be required if the end products were carbon dioxide and water. They do, however, run parallel, in a measure, to the iodine numbers. We can see nothing to be gained by the employment of such a method. The determination of the iodine number is easier of manipulation, requires less time, and is more accurate. The work in other directions is being continued.

SUMMARY.

We have demonstrated both experimentally and from the known behavior of potassium permanganate that the method advanced by Hodgson for the determination of an "oxygen equivalent" for fats and oils has no theoretical or experimental foundation.

The products of saponification of the different fats and oils do require varying amounts of potassium permanganate for their oxidation. These amounts are, in a measure, parallel to the iodine numbers.



MAP OF LAGUNA DE BAY SHOWING THE REGIONS FROM WHICH THE CLAY WAS TAKEN.

LAGUNA CLAYS.

By ALVIN J. COX.

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This investigation was undertaken at the request of the Bureau of Education to enable it to choose a clay for use in the pottery school, the building for which is now being erected in Santa Cruz. None of the clay deposits of Laguna Province have been thoroughly studied up to the present time and, therefore, I will first discuss those so situated that the stripping of the material would entail the least labor and the soil overlying could easily be disposed of. Such clays would be economical to use were they of high grade.

A paper on the clays from the Island of Luzon has already been published[1] in which the uses and the chemical and physical behavior of some of the Laguna clays and the influence of the fluxes were thoroughly discussed. The data there given are to a great extent directly applicable to the samples treated in this paper and the application is so simple that the interested reader may make it for himself. The following statement regarding kaolin may assist in the proper interpretation of the results given below.

The composition of pure kaolin (kaolinite) calculated from the theoretical formula $Al_2O_3.2SiO_2.2H_2O$ is—

	Per cent.
Silica (SiO_2)	46.65
Alumina (Al_2O_3)	39.45
Water (H_2O)	13.90
Total	100.00

Examinations of kaolins from Harris Company, Webster, North Carolina,[2] and from Glen Allen, Missouri,[3] are as follows:

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[1] Cox, Alvin J., *This Journal, Sec. A.*, (1907), **2**, 413.

[2] N. C. Geol. Sur. (1897). Bull. 13, 59 et seq.

[3] Mo. Geol. Sur. (1896), **11**, 578 et seq.

Chemical analyses.

[Figures give percentages.]

Source.	Silica (SiO_2).	Alumina (Al_2O_3).	Fluxes.						Water (H_2O).		Titanium oxide (TiO_2).	Total fluxes.
			Ferric oxide (Fe_2O_3).	Ferrous oxide (FeO).	Lime (CaO).	Magnesia (MgO).	Soda (Na_2O).	Potash (K_2O).	Above 110°.	Below 110°.		
Crude kaolin Webster, N. C	62.40	26.51	1.14	------	0.57	0.01	0.98		8.80	0.25	------	2.70
Washed kaolin, Webster, N. C	45.78	36.46	0.28	1.08	0.50	0.04	0.25		13.40	2.05	------	2.15
Glen Allen, Mo	72.30	18.94	0.40	------	0.68	0.39	0.42		7.04	------	------	1.91

Physical properties.

Source.	Water added to give a workable paste (per cent total weight).	Tensile strength of the air-dried sample.		Shrinkage (per cent).		
		Kilo per square centimeter.	Pounds per square inch.	Air.	Fire at cone No. 9.	Total.
Webster N. C	42.0	1.55	22	6	4	10
Glen Allen, Mo	23.2	0.84	12	4	8.4	12.4

The chemical composition of the clays given below shows them as they occur and may include impurities that may be removed by washing, sieving, etc.

MATIQUIO.

The outcrops appear at various places along the Butadero River northwest of Matiquio. Three outcrops, which have been staked by Laguna Province, are about an hour's walk from Matiquio. They are very close together, the prismatic compass shows them to be 13° west of north of Pila and the aneroid barometer shows their altitude to be 240, 300 and 270 meters, respectively. The natives report that formerly 1,000 five-kilo baskets were taken from this point and shipped for use at Bilibid. All three of these outcrops are on the steep hillside, perhaps 40 meters above the river. The clay slopes wash down easily and one outcrop was so obliterated that it was impossible to obtain a sample. The other two were readily uncovered and show that most of the thoroughly weathered clay has been removed, or that the material has not yet been completely weathered. Most of the post-auger holes gave very gritty and imperfectly weathered samples. They all contain pyrites, which will prevent their burning to a white product.

A light gray sample of fair quality was taken from the lowest outcrop. Three determinations gave its tensile strength as 4.8 kilograms per square centimeter (68.3 pounds per square inch) and its air shrinkage as 1.4 per cent.

Continuing up the Butadero River, on the left there is a large outcrop of clay about 3 meters wide and 4 meters high just above the high-water line. On the surface it is bleached to a whitish color, but a few centimeters below it is blue. This clay contains pyrites and grit which unfit it for pottery use in the raw state. A short distance farther up, the Sunka Sunka and the Kaloong Rivers join to form the Butadero. About a half kilometer up the Kaloong on the right is a perfect illustration of the breaking down of the basal rock in the formation of residuary clay deposits, but the decomposition of the deposit has not continued far enough to form any considerable quantity of good clay. On the ridges the decomposition is very incomplete and the clay is full of unweathered rock fragments and pyrites. In the water channels and moist places the decomposition is fairly complete, but these areas are neither large nor numerous. However, a sample from one of these places was the best that I found in the Matiquio region, and when subjected to laboratory examination gave the following results:

Chemical analysis.

[Figures give percentages.]

Silica (SiO_2).	Alumina (Al_2O_3)	Fluxes.						Loss on ignition.[a]	Water (H_2O) below 110°.	Titanium oxide (TiO_2).	Sulphur.	Total fluxes.
		Total iron given as ferric oxide (Fe_2O_3)	Lime (CaO).	Magnesia (MgO).	Soda (Na_2O).	Potash (K_2O).						
61.00	19.71	3.48	0.34	0.07	0.23	0.61		8.18	5.97	0.95	--------	4.73
[b]64.8	[b]20.96	[b]3.70	[b]0.36	[b]0.07	[b]0.24	[b]0.65		[b]8.70	[b]0.00	[b]1.01	--------	[b]5.02

[a] Mostly water above 110°. [b] Recalculated free from water below 110°.

Physical properties.

Water added to give a workable paste (per cent total weight).	Tensile strength.				Shrinkage (per cent).			Color.	
	Air dried, 3 determinations averaged.		Burned, 4 determinations averaged.		Air.	Fire, at cone No. 9.	Total.	Air dried.	Burned with free access of air.
	Kilos per square centimeter.	Pounds per square inch.	Kilos per square centimeter.	Pounds per square inch.					
22.4	8.47	49.8	9.07	129	4.7	+0.4	4.3	Light gray ---	Light gray.

The iron content of this sample is so large that the clay could not be expected to yield a white product, but its physical properties, particularly its plasticity, tensile strength and shrinkage are such as to make it useful in the manufacture of colored wares. The clay does not crack in burning. In the future these deposits will probably be valuable, but the outcrop indicates that the supply at present would be quite limited without a laborious and expensive system of troughs and tanks. Such operations would not pay except on a clay of the highest quality. A limited amount of this clay could probably be mined and especially because of its low shrinkage would be used to recompose other clays which in some ways have more desirable physical properties.

MAJAYJAY.

The deposit at Majayjay is on Mangulila Creek about 30 or 40 meters from its mouth where it empties into the Dalatiuan River at an altitude of 180 meters. It is 300 or 400 meters above the point at which the Majayjay-Lucban trail crosses the Dalatiuan gorge. There is a large amount of clay in sight. On the left side of Mangulila Creek the clay is exposed in a bank 15 or 20 meters long and about 4 meters high. This material is probably of sedimentary origin. I removed the surface and thoroughly investigated the clay. It is very uniform in quality and plasticity, free from grit and bluish in color when wet. The exposed surface is yellowish, unquestionably because of the fixation as oxide of the large amount of iron which the clay contains. The deposit appears to extend under the stream and outcrops on the right bank in a much whiter condition, but under large boulders. Samples of the deposit were carefully taken on both sides of the river and investigated in the laboratory. The two were found to be almost identical in their general characteristics. The data and results are as follows:

Chemical analysis of the clay from the left bank.

[Figures give percentages.]

Silica (SiO_2).	Alumina (Al_2O_3)	Fluxes.					Loss on ignition.[a]	Water (H_2O) below 110°.	Titanium oxide (TiO_2).	Sulphur.	Manganese oxide (MnO).
		Total iron given as ferric oxide (Fe_2O_3)	Lime (CaO).	Magnesia (MgO).	Soda (Na_2O).	Potash (K_2O).					
					(By difference.)						
39.55	28.11	10.27	0.35	0.33	0.17		13.62	6.25	1.05	--------	trace.
[b] 42.15	[b] 30.3	[b] 10.94	[b] 0.37	[b] 0.35	[b] 0.18		[b] 14.50	[b] 0.00	[b] 1.12	--------	[b] trace.

[a] Mostly water above 110°.

[b] Recalculated free from water below 110°.

Physical properties of the clay from the left bank.

Water added to give a workable paste (per cent total weight).	Tensile strength.				Shrinkage (per cent).			Color.	
	Air dried.		Burned.						
	Kilos per square centimeter.	Pounds per square inch.	Kilos per square centimeter.	Pounds per square inch.	Air.	Fire.	Total.	Air dried.	Burned.
37.0	1.9	[a]27	none.	[b]none.	8.65	17.5	26.15	Yellowish-gray	Red.

[a] 8 of the 9 briquettes were so badly cracked that they were not usable.

[b] Cracks open in all directions and the briquettes warp badly.

Physical properties of the clay from the right bank.

Water added to give a workable paste (per cent total weight).	Tensile strength.				Shrinkage (per cent).			Color.	
	Air dried, 2 determinations averaged.		Burned.						
	Kilos per square centimeter.	Pounds per square inch.	Kilos per square centimeter.	Pounds per square inch.	Air.	Fire.	Total.	Air dried.	Burned with free access of air.
30.0	1.55	22	none.	[a]none.	8.5	14.8	23.3	Gray	Red.

[a] Cracks open in all directions and the briquettes warp badly.

The red color of the burned product and the abnormally great fire shrinkage indicate that this clay is worthless for the manufacture of fired products, furthermore the product cracks badly upon air drying.

BOTOCAN.

There is a peculiar ridge of red clay which is said to extend nearly all the way from Lucban to Pagsanjan. As it exists in such large quantities I thought it might be of commercial value and a small sample was taken about a hundred meters south of the barrio of Baquio. Its analysis and physical properties are as follows:

Chemical analysis.

[Figures give percentages.]

Silica (SiO_2).	Alumina (Al_2O_3).	Fluxes.					Loss on ignition.[a]	Water (H_2O) below 110°.	Titanium oxide. (TiO_2).	Manganese oxide (MnO).
		Total iron given as ferric oxide (Fe_2O_3).	Lime (CaO).	Magnesia (MgO).	Soda (Na_2O).	Potash (K_2O).				
34.55	28.73	12.77	0.00	0.16	small.	small.	13.02	10.09	1.17	0.06
[b]38.4	[b]31.9	[b]14.2	[b]0.00	[b]0.18	[b]small.	[b]small.	[b]14.47	[b]0.00	[b]1.30	[b]0.07

[a] Mostly water above 110°.

[b] Recalculated free from water below 110°.

Physical properties.

Water added to give a workable paste (per cent total weight).	Tensile strength.				Shrinkage (per cent).			Color.	
	Air dried.		Burned.						
	Kilos per square centimeter.	Pounds per square inch.	Kilos per square centimeter.	Pounds per square inch.	Air.	Fire.	Total.	Air dried.	Burned with free access of air.
36.4	>0.15	>2.2	....	....	14.0	17.5	31.5	Dark red.	Very dark red.

This clay on burning gives a very dense, hard body and a good paving brick might possibly be manufactured from it by recomposing it to increase its tensile strength and overcome its cracking in the air.

MOUNT MAQUILING REGION.

The clays of this region are the only true kaolins that I have seen in Laguna Province. The knowledge of their existence dates back to Spanish times, but their extent is not known. The outcrops in all of these deposits have been very much worked over and in such a manner that it is not easy to obtain very many particulars concerning them. The laborer digs a hole through the overburden just large enough to admit his body; when he reaches the kaolin he burrows it out in every direction as far as he can without danger to himself. When he has exhausted one hole he goes a little farther and digs another. Sometimes the strippings from the second hole have been thrown into the first and even when this has not been done, since the deposits are in all cases on the mountain side, slides and washes have filled all the old workings and it is impossible to estimate either the amount of overburden or the extent of the deposits. Only systematic boring or the uncovering of a large area can determine this.

LOS BAÑOS.

This deposit is 6 or 8 kilometers from the lake, southeast of Los Baños on the mountain side above Bagong Bola Creek. This is the only deposit known to the natives and is reached by a very poor trail. The highest point on the trail is about 370 meters, while the deposits are about 350 meters above sea level. The natives say that no clay has been taken from this point since Spanish times. One man informed me that he formerly made excavations here and that many of the pits were dug to a depth of five meters. There are scores of holes partially or almost completely filled by wash; their existence indicates that the deposit extends over a considerable area. In several places there are appearances of an outcrop, but closer examination shows them to be only excavated material cast aside by the miners and proves that no superficial examination can possibly reveal much regarding the thickness or extent of the deposit.

I opened up two of the old pits which I thought perhaps representative. I excavated one to a depth of over two meters and then bored on a slant in two directions with a post-hole auger for 1½ meters more. On one side the material was gritty and only partially weathered, while on the other a very good, uniform, sample of kaolin was obtained. The latter was investigated in the laboratory with the following results:

Chemical analysis.

[Figures give percentages.]

Silica (SiO_2).	Alumina (Al_2O_3)	Fluxes.					Loss on ignition.[a]	Water (H_2O) bellow 110°.	Titanium oxide (TiO_2)	Manganese oxide (MnO).	Total fluxes.
		Total iron given as ferric oxide (Fe_2O_3)	Lime (CaO).	Magnesia (MgO).	Soda (Na_2O).	Potash (K_2O).					
49.42	30.45	1.61	0.00	0.21	0.07	0.09	11.72	5.86	1.11	trace.	1.98
[b]52.45	[b]32.3	[b]17.1	[b]0.00	[b]0.22	[b]0.07	[b]0.10	[b]12.43	[b]0.00	[b]1.18	[b]trace.	[b]2.10

[a] Mostly water above 110°. [b] Recalculated free from water below 110°.

Physical properties.

Water added to give a workable paste (per cent total weight)	Tensile strength.				Shrinkage (per cent).			Color.	
	Air dried.		Burned.[a]						
	Kilos per square centimeter.	Pounds per square inch.	Kilos per square centimeter.	Pounds per square inch.	Air.	Fire at cone No. 9.	Total.	Air dried.	Burned with free access of air.
38.6	1.56	22.2	4.22	60	5.2	6.3	11.5	Creamy white	Light creamy white.

[a] Does not crackle.

The other pit excavated to a depth of a meter and then bored on a slant in one direction yielded quite a different sample. This contained a small amount of pyrites and when moist was of a bluish tint. The natives say that material of this quality formerly overlay the whole deposit of white clay. The laboratory data and results on this sample are as follows:

Chemical analysis.

[Figures give percentages.]

Silica (SiO_2).	Alumina (Al_2O_3).	Fluxes.					Loss on ignition.[a]	Water (H_2O) below 110°.	Titanium oxide (TiO_2)
		Total iron given as ferric oxide (Fe_2O_3).	Lime (CaO).	Magnesia (MgO).	Soda (Na_2O).	Potash (K_2O).			
43.83	31.86	5.86	0.14.	0.11	small	small.	15.04	2.71	0.80
[b]45.0	[b]32.7	[b]6.03	[b]0.15.	[b]0.11	[b]small	[b]small.	[b]15.44	[b]0.00	[b]0.82

[a] Mostly water above 110°. [b] Recalculated free from water below 110.°

Physical properties.

Water added to give a workable paste (per cent total weight).	Tensile strength.				Shrinkage (per cent).			Color.	
	Air dried.		Burned.						
	Kilos per square centimeter.	Pounds per square inch.	Kilos per square centimeter.	Pounds per square inch.	Air.	Fire.	Total.	Air dried.	Burned with free access of air.
33.7	---- ----	--------	8.44	120.	4.65	4.25	8.9	Light grayish-white.	Bluish-white.

[a] Crackles considerably.

These three samples taken together may indicate that the material is still in the process of formation and that formerly only the pockets of the best clay were sought and worked out. Both the chemical and physical characteristics of these two samples indicate them to be suitable for use in the manufacture of a good class of pottery, but probably a large amount of sorting would be necessary in the mining of the clay.

CALAMBA.

Two kaolin deposits are known in the region of Calamba; one in the Pajo Cañon and the other below Point Alipasio, overlooking the Santo Tomas Road.

A pony trail on the right side of the cañon leads to the former; it is steep in places but fairly passable in the dry season. This deposit is about two or three kilometers from the lake and at an altitude of about 200 meters. There are outcrops on both sides of the cañon, but like those of Los Baños, they have been disturbed until definite information regarding them is difficult to obtain. The natives say that on the right side of the cañon the clay is the whitest that has ever been found. I made several borings at spots indicated by men familiar with the deposit. Some samples were white, streaked with black, perhaps vegetable matter, but one was uniformly white. Since it is claimed that the latter was not an unusual pocket I have studied the sample in the laboratory, obtaining the following data and results:

Chemical analysis.

[Figures give percentages.]

Silica (SiO_2).	Alumina (Al_2O_3).	Fluxes.					Loss on ignition.[a]	Water (H_2O) below 110°.	Titanium oxide (TiO_2).	Total fluxes.
		Total iron given as ferric oxide (Fe_2O_3).	Lime (CaO).	Magnesia (MgO).	Soda (Na_2O).	Potash (K_2O).				
55.99	28.77	0.89	0.18	0.03	0.08	0.09	11.59	2.42	0.91	1.27
[b]57.4	[b]29.47	[b]0.91	[b]0.19	[b]0.03	[b]0.08	[b]0.09	[b]11.87	[b]0.00	[b]0.93	[b]1.30

[a] Mostly water above 110°.

[b] Recalculated free from water below 110.°

Physical properties.

Water added to give a workable paste (per cent total weight).	Tensile strength.				Shrinkage (per cent).			Color.	
	Air dried.		Burned.[a]						
	Kilos per square centimeter.	Pounds per square inch.	Kilos per square centimeter.	Pounds per square inch.	Air.	Fire, at cone No. 9.	Total.	Air dried.	Burned with free access of air.
36.3	2.71	38.6	3.5	50	3.06	7.64	10.7	Light cream.	Light creamy-white.

[a] Burns excellently.

The deposits were being worked on the other side of the Pajo River at the time of my visit; the product is sacked and carried on the backs of natives or ponies to the barrio of Bukal on the lake shore where it is made into balls and shipped to Manila. The material as mined is more or less streaked with red, but when the less plastic lumps are discarded and when macerated it works up to a light cream and is bought by the Chinese of Binondo, who make of it a sort of whitewash which is said to be better than the whiter product above mentioned, perhaps because of its greater tensile strength. Certain of the physical properties, especially the behavior under fire, have no significance when a material is used for covering walls. The open workings indicate a considerable amount of this class of clay. Two of the pits were sampled. The lowest opening on the mountain side was carefully cleaned out to a depth of at least two meters and then I took an average sample of the material, which I removed from a meter bore-hole in the bottom. The clay from this pit was accepted by the natives without sorting.

The data and results of the laboratory tests of the sample are as follows:

Chemical analysis.

[Figures give percentages.]

Silica (SiO_2).	Alumina (Al_2O_3).	Fluxes.					Loss on ignition.[a]	Water (H_2O) below 110°.	Titanium oxide (TiO_2).	Total fluxes.
		Total iron given as ferric oxide (Fe_2O_3).	Lime (CaO).	Magnesia (MgO).	Soda (Na_2O).	Potash (K_2O).				
42.23	37.82	1.41	0.23	0.07	0.11	0.35	15.84	1.92	1.00	2.17
[b]43.1	[b]38.05	[b]1.44	[b]0.23	[b]0.07	[b]0.11	[b]0.36	[b]16.14	[b]0.00	[b]1.02	[b]2.21

[a] Mostly water above 110°. [b] Recalculated free from water below 110.°

Physical properties.

Water added to give a workable paste (per cent total weight).	Tensile strength.				Shrinkage (per cent).			Color.	
	Air dried, 4 determinations averaged.		Burned,[a] 3 determinations averaged.		Air.	Fire at cone No. 9.	Total.	Air dried.	Burned with free access of air.
	Kilos per square centimeter.	Pounds per square inch.	Kilos per square centimeter.	Pounds per square inch.					
25.4	3.78	53.8	4.00	57	3.06	11.1	14.16	Creamy-white.	Rose-cream.

[a] Crackles to a certain extent.

Another and larger opening about ten meters from this and about three or four meters higher was also sampled. This pit had been burrowed out in every direction to a depth of 2 meters. I excavated a third meter and bored still a fourth to obtain my sample. It was an average of the run of the deposit and showed more red streaks than the former sample and had an extremely mottled appearance. In this pit the natives sorted and discarded the less plastic lumps. The tensile strength of my sample will be seen to be lower than that obtained from the other pit, but it is believed that the clay removed by the carriers was of about the same quality.

The data and results of the laboratory tests are as follows:

Chemical analysis.

[Figures give percentages.]

Silica (SiO_2).	Alumina (Al_2O_3).	Fluxes.					Loss on ignition.[a]	Water (H_2O) below 110°.	Titanium oxide (TiO_2).
		Total iron given as ferric oxide (Fe_2O_3).	Lime (CaO).	Magnesia (MgO).	Soda (Na_2O).	Potash (K_2O).			
43.28	37.85	3.39	0.08	0.04	small.	small.	14.2	0.89	1.25
[b]43.7	[b]38.2	[b]3.4	[b]0.08	[b]0.04	[b]small.	[b]small.	[b]14.3	[b]0.00	[b]1.25

[a] Mostly water above 110°.

[b] Recalculated free from water below 110°.

Physical properties.

Water added to give a workable paste (per cent total weight).	Tensile strength.				Shrinkage (per cent).			Color.	
	Air dried, 3 determinations averaged.		Burned.[a]		Air.	Fire at cone No. 9.	Total.	Air dried.	Burned with free access of air.
	Kilos per square centimeter.	Pounds per square inch.	Kilos per square centimeter.	Pounds per square inch.					
26.6	1.64	23.3	2.95	42	1.6	9.6	11.2	Cream	Pale lilac.

[a] Crackles to a certain extent.

Some of the natives state that they have made excavations as deep as four meters, but although they worked regularly in these deposits they showed such timidity about entering the pits that I doubt if they often go deeper than the holes which were open during my visit.

The information gained from the chemical and physical tests of this deposit indicate the usefulness of this material for making certain grades of pottery.

The deposit below Point Alipasio in the region of Calamba is at an altitude of 210 meters and has apparently been very little, if ever, worked. It is on the dry side of the mountain and the weathering has taken place very much more slowly; moreover the deposit is quite hot and the heat soon dries out the water which is perhaps the chief desintegrating factor in a tropical country, this prevents further action. In some places the basal rock is scarcely decomposed at all, at others there is a thin layer of completely weathered, grayish clay, while in still others there are pockets probably of no great extent, of a good quality of kaolin.

One of these at the base of the deposit was sampled and investigated in the laboratory. The data and results are as follows:

Chemical analysis.

[Figures give percentages.]

Silica (SiO_2).	Alumina (Al_2O_3).	Fluxes.					Loss on ignition.[a]	Water (H_2O) below 110°.	Titanium oxide (TiO_2).	Total fluxes.
		Total iron given as oxide ferric (Fe_2O_3).	Lime (CaO).	Magnesia (MgO).	Soda (Na_2O).	Potash (K_2O).				
43.16	38.64	1.19	0.09	0.14	0.08	0.02	14.55	1.42	1.54	1.52
[b]43.77	[b]39.20	[b]1.20	[b]0.09	[b]0.14	[b]0.08	[b]0.02	[b]14.75	[b]0.00	[b]1.56	[b]1.53

[a] Mostly water above 110°. [b] Recalculated free from water below 110°.

Physical properties.

Water added to give a workable paste (per cent total weight).	Tensile strength.				Shrinkage (per cent).			Color.	
	Air dried, 6 determinations averaged.		Burned.[a]						
	Kilos per square centimeter.	Pounds per square inch.	Kilos per square centimeter.	Pounds per square inch.	Air.	Fire.	Total.	Air dried.	Burned with free access of air.
34.9	1.81	25.8	1.9	27.1	6.1	13.3	19.4	Bluish-white	Cream.

[a] Crackles badly.

The physical properties of the grayish clay are as follows:

Water added to give a workable paste (per cent total weight).	Tensile strength.				Shrinkage (per cent).			Color.	
	Air dried.		Burned.[a]						
	Kilos per square centimeter.	Pounds per square inch.	Kilos per square centimeter.	Pounds per square inch.	Air.	Fire at cone No. 9.	Total.	Air dried.	Burned with free access of air.
33.4	1.75	24.9	2.39	34	4.65	14.2	18.85	Grayish-white	Cream.

[a] Crackles badly.

Still another very light-gray sample was taken at a distance of 30 or 40 meters. Three determinations gave its tensile strength as 2.4 kilograms per square centimeter (34.2 pounds per square inch) and its air shrinkage as 2.4 per cent.

At some future time the disintegration of this deposit will have produced a sufficient quantity of clay to justify its use for the manufacture of pottery.

There is a Japanese in Los Baños who is successfully molding various kinds of small objects from Calamba clay. He has very primitive appliances and his products are all underburned, but his work indicates that with proper handling, satisfactory results probably could be obtained with this clay.

The indications are that all of the high grade clays of Laguna Province are more or less mixed with clay of poorer quality. It is a question what percentage of the mixture is useful and whether the expense of sorting will not be so great that it can not compete with kaolin from other sources.

ILLUSTRATION.

Facing page—
Map of Laguna de Bay showing the regions from which the clay was taken.. 377

VOLCANIC TUFF AS A CONSTRUCTION AND A CEMENT MATERIAL.

By Alvin J. Cox.

(From the Labortory of Inorganic and Physical Chemistry, Bureau of Science, Manila, P. I.)

In the Philippines the varieties of stone which are known to be good for building and construction purposes are not very numerous. Moreover it is unfortunate that those that exist are not conveniently located for use. Since the first cost is the controlling factor in the purchase of materials for construction, a very poor substitute must often be used.

The metamorphic and igneous rocks, capable of resisting heavy strains and weathering, which have been noted on many of the Islands of the Philippines by the early explorers,[1] and by Becker,[2] McCaskey and Ickis,[3] Eveland,[4] Smith,[5] Ferguson[6] and others of recent time, embrace:

A. Metamorphic:

Breccias, gneisses, schists and serpentines.

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[1] Meyen and Itier, J.: Reise um die Erde (1835). **2**, 237; Itier, J.: *Bull. Soc. geog.* Paris, 3d. (1845), **5**, 365 *et seq.*; Roth, J.: F. Jagor's Reisen in den Philippinen, Berlin (1873), 344; Centeno, José: Memoria geologico-minera de las Islas Filipinas, Madrid (1876), 19; Von Drasche, R.: Fragmente zu einer Geologie der Inzel Luzon, Vienna (1878), 20 *et seq.*; Oebbeke: *Neues Jahrbuch, Beilage* (1881), **1**, 495–8; Renard, A. F.: In the Report of the Exploring Voyage of H. M. S. Challenger, London (1889), **2**, Pt. 4, 160–175; Abella, Enriqué: El Mayón, Madrid (1885); El monte Maquilin, Madrid (1885); La Isla de Biliran, Madrid (1885); Rápida descripcion fisica, geológica y minera de la Isla de Cebu (1886), 96–101; Descripcion fisica, geológica y minera en bosquejo de la Isla de Panay, Manila (1890), 97 *et seq.*; Manantiales minerales de Filipinas, Manila (1893), 16, 18, 31, 75, 144, etc.; Terremotos experimentados en la Isla de Luzon, etc., Manila (1893), 32 *et seq.*; etc. Dr. Becker gives a bibliography of the early books and papers on Philippine Geology, U. S. G. S. 21st Ann. Rep. (1902), 594.

[2] Becker, G. F.: loc. cit., 561.

[3] McCaskey, H. D. and Ickis, H. M.: Sixth Ann. Report of the Mining Bureau, Manila (1905), 57.

[4] Eveland, A. J.: *Bull. Min. Bur.*, Manila (1905), 4.

[5] Smith, W. D.: *Ibid.*, **5**; *This Journal* (1906), **1**, 203, 617, 1043; *Ibid.*, *Sec. A.*, **2**, 145, 253.

[6] Ferguson, H. G.: *This Journal*, Sec. *A.* (1907), **2**, 407.

B. Deep seated igneous:

Diabases, diorites, gabbros, granites, quartz porphyry (dike rock), peridotites, pyroxenites, tonalite, and syenites.

C. Volcanic:

Andesites, basalts, rhyolites, dacites and trachytes.

Some of these are merely enumerations, for no microscopic or special study of them has been made. On the other hand it is probable that the known quantities are but a small proportion of those that actually exist because of the meager exposures in the mountains and ravines, many outcrops being entirely obliterated by covers of soil and heavy tropical vegetation, and because certain districts have not yet been explored.

It would be out of place here to discuss the distribution of these rocks. However, it might be mentioned that the diorites and the andesites of the second and third classes, respectively, are the most generally distributed. The former occur very extensively in the Cordillera and the latter in the Mariveles district, which forms the northern headland of Manila Bay. The latter district is now being extensively mined by the Atlantic, Gulf and Pacific Company for use in connection with the sewer construction in Manila.

Limestone occurs widely distributed practically throughout all the Islands.

Goodman[7] reports limestone at Dumalag and Pilar, Province of Capiz, "appearing especially compact and seemingly fit for a building stone. In fact the church at Dumalag, which was erected in 1873, as well as other buildings in the town are constructed of this material. I noticed, however, that some of the blocks in the church showed marked effects of weathering. Although fairly compact, I do not believe that the Dumalag limestone is any more so than that which may be quarried near Binangonan on Laguna de Bay, this latter having the further advantage of being much nearer to Manila and to tide water."

Mr. Goodman also reports with regard to tonalite that: "At the foot of Mount Anjaoan, which is just off the main road and about a quarter of a mile southwest of Colasi, is a massive outcrop of the tonalite which Abella reports as occurring in this neighborhood. At Mount Deluca, a low hill about one hundred feet high and about one and a quarter miles west of Anjaoan, the tonalite takes on a grayer color, but in texture and mineral composition remains the same. The same rock occurs again at Mount Jilonoc which is about the same height as Mount Deluca and about one and a half miles west of it. Outcrops of tonalite are encountered in various other places along the road between Colasi and the barrio of San Fernando, and there in but little doubt that practically the same formation continues for at least three miles east of Anjaoan. A thick growth of cogon covers these hills so as to expose but comparatively small surfaces of the rock in place, and these all appear massive, no systematic jointing being observable. The stone is uniform and close grained, compact and hard, takes a good polish and seems well adapted for use in heavy construction. It is well located too with a view to quarrying and transportation. The harbor at Colasi, however, did not strike me as nearly so perfect a one as I had expected and hoped to find it."

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[7] An unpublished report made to the Chief of the Division of Mines, Bureau of Science (1906), January.

In addition to the rocks mentioned above, volcanic sediments and pyroclastic tuffs occur quite widely distributed in the Philippines. They are especially abundant in west central Luzon, extending almost unbrokenly from near Lingayen Gulf to the seacoast of Batangas, practically blanketing or covering nearly all of the massive rocks of this region. Mr. Ickis found volcanic tuff in the Agusan-Pulangui region, interior from Cagayan, Misamis.

In the absence of a better stone, in certain places this has been used extensively for building purposes. In Bulacan and along the Pasig River, especially near Guadalupe, this stone is unusually abundant. Large quantities of it have been quarried and used in the construction of many churches and other buildings and in the walls and fortresses of Manila. It is very workable. Before it is disturbed it is so soft that it can be quarried with an axe, but it hardens rapidly on exposure.

Since American occupation the competition of brick and other manufactured products in Manila has encroached upon the general use of volcanic tuff, nevertheless a large quantity still finds a market. Owing to the extended use of this stone I have made a few experiments to show its real value. The most important laboratory tests which aid one to form an opinion as to the value of a stone are the microscopical, physical, and chemical examinations. Such tests are given below:

MICROSCOPICAL EXAMINATION.

A microscopic examination of the tuff in the vicinity of Manila shows it to be composed of (1) plagioclase, both decomposed and undecomposed. There seem to be two generations of feldspar; the one rounded and largely decomposed, the other rather angular and in appearance as if it had come from a greater distance, (2) magnetite, (3) hornblende, (4) quartz grains, (5) the cementing material, which is probably in greater part volcanic ash, is largely composed of oxide of iron. It might also be mentioned that a certain amount of pumice is nearly always to be found in this tuff. It is undoubtedly andesitic tuff. Silica is the strongest and most desirable bonding material because it is insoluble, free from cleavage and has the same coefficient of expansion as the sand grains which it holds together; however, iron oxides make a fair bond. The latter are more desirable as a cementing material than calcite which is soluble, has very pronounced cleavage, and has a different coefficient of expansion from that of the mineral grains which it holds together, or than clayey matter which is liable to disintegrate.

PHYSICAL EXAMINATION.

The *crushing strength* of a few samples of tuff has been determined. The object of such tests in stone is to discover the relation between the crushing strength and the stress to which it would be subjected in a high wall. It is difficult to say what is the effect of long continued pressure upon a stone under this condition, but the majority of architects estimate that ten or twenty times the strength to which it is actually subjected is required. The data are as follows:

TABLE I.—*Crushing strength of andesitic tuff from near Manila.*

Source.	Number of determinations made.	Average area of bearing surface.	Ultimate strength per square centimeter.		
			Maximum.	Minimum.	Average.
		Sq. cm.	*Kilos.*	*Kilos.*	*Kilos.*
Manila, quarry unknown	2	73.3	101	85	93
Guadalupe quarry	4	93.5	42	30	39.3
Baliuag	7	54.	205	110	151
Majayjay, Laguna quarry	3		194	166	181
Do.[a]	2		157	141	149

[a] An old stone which had been used many years in a building. It showed marked sign of decay.

Using the average value given for the Majayjay quarry stone and the weight for the wet stone as 1,655 kilograms per square meter (given on p. 399) it can be computed that a wall 110 meters high would be required to equal the compression strength of the stone. Using the safety factor 10, this would be suitable for the erection of structures eleven meters high.

Much of the stone from the Meycauayan quarries, Province of Bulacan, which supply stone to Manila is of this class and is fairly durable. The stone formerly quarried in Guadalupe seems to be better than that which is now being taken out. Probably many of the best quarries there and possibly elsewhere have been lost sight of, for recently quantity rather than quality has been sought, i. e., no attention has been paid to systematic testing and that stone which was most accessible has been worked regardless of its grade.

Rondelet's rule that the resistance of a stone to crushing is only three times that offered to traction does not hold for volcanic tuff.

The *tensile strength* of a stone is its ability to withstand a pulling stress. This has been determined for several samples. These determinations were made by cutting blocks of the stone of the ordinary size and shape of a cement briquette and breaking them in a standard machine. The rate of the shot in all of these tests was 183 kilos per minute, that adopted by the United States Army in their specifications for cement.

Three samples of stone which to my knowledge have been quarried at least two years, taken from various sources in Manila, showed the following tensile or breaking strength.

TABLE II.—*Tensile strength of stone being used in Manila.*

Sample.	Number of determinations made.	Tensile strength per square centimeter.			Tensile strength per square inch.		
		Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.
		Kilos.	*Kilos.*	*Kilos.*	*Lbs.*	*Lbs.*	*Lbs.*
1	7	7.38	4.85	5.77	105	69	82
2	4	5.70	5.27	5.48	81	75	78
3	2	8.23	4.64	6.40	117	66	91

A sample of stone taken from the Majayajay, Laguna quarry gave the following results:

TABLE III.—*Tensile strength of Majayjay stone.*

Number of determinations made.	Tensile strength per square centimeter.			Tensile strength per square inch.		
	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.
	Kilos.	*Kilos.*	*Kilos.*	*Lbs.*	*Lbs.*	*Lbs.*
3	10.05	6.61	8.79	143	93	125

The *transverse strength* of a stone is the ability to withstand a stress applied at right angles to the length of the block. Its determination is valuable in estimating the thickness of stone required when supported only at the ends or uniformly from end to end. The cracking of stone and brick walls or of single blocks is usually the result of transverse stress due to unequal support throughout their length.

The transverse strength of a number of samples was determined in the following manner. Samples having a cross section of approximately 2.5 by 2.5 centimeters, and a length of 18 to 20 centimeters were prepared; after air drying in my laboratory they were dried at 100° and finally broken in a testing machine.

The modulus of rupture was computed from the following formula:

$$W=\frac{2bh^2}{3l}R \text{ from which } R=\frac{3l}{2bh^2}W \text{ where}$$

W=concentrated load at center in kilograms
b=breadth in centimeters
h=depth in centimeters
l=length in centimeters
R=modulus of rupture in kilograms per square centimeter.

The results are as follows:

TABLE IV.—*Transverse strength.*

Source.	No. of test.	Length.	Breadth.	Height.	Weight of load.	Modulus of rupture per square centimeter.
		Cm.	*Cm.*	*Cm.*	*Kilos.*	*Kilos.*
Manila, quarry unknown	a	15.24	2.72	2.89	15.64	15.74
	b	15.24	2.81	2.97	21.54	19.86
Guadalupe quarry [a]	a	15.24	2.61	2.83	18.38	20.10
	b	15.24	2.77	2.84	27.68	28.32
Guadalupe quarry	a	15.24	2.75	2.75	12.70	13.96
	b	15.24	2.78	2.85	15.44	15.64
	c	15.24	2.61	2.73	12.24	14.38
	d	15.24	2.55	2.82	13.16	14.84
	e	15.24	2.72	2.78	10.43	11.76
	f	15.24	2.67	2.63	9.30	11.51
	g	15.24	2.77	2.81	10.20	10.66
	h	15.24	2.72	2.75	11.33	12.59
	i	15.24	2.59	2.65	9.52	11.97
Guadalupe quarry [b]	a	15.24	2.79	2.67	10.20	11.72
	b	15.24	2.78	2.85	10.44	10.57
Guadalupe quarry [c]	a	15.24	2.78	2.88	9.75	9.67
	b	15.24	2.74	2.92	10.88	10.65
Baliuag quarry	a	15.24	2.76	2.67	18.10	21.00
	b	15.24	2.74	2.68	17.20	20.00
Majayjay, Laguna quarry	a	15.24	2.68	2.52	19.96	26.81
	b	15.24	2.60	2.88	32.66	34.62
	c	15.24	2.62	2.57	24.95	32.96
	d	15.24	2.63	2.57	20.43	26.89
	e	15.24	2.53	2.84	19.96	22.36
	f	15.24	2.76	2.82	32.00	33.33
	g	15.24	2.82	2.86	21.77	21.58
	h	15.24	2.67	2.72	27.90	32.29
Majayjay, quarry unknown [d]	a	15.24	2.61	2.68	20.87	25.45
	b	15.24	2.62	2.83	13.17	14.35
	c	15.24	2.63	2.83	13.62	14.78
	d	15.24	2.77	2.70	24.06	27.24
	e	15.24	2.66	2.78	26.84	30.37
	f	15.24	2.68	2.77	24.06	26.75
	g	15.24	2.47	2.78	20.43	24.47

[a] An unused block taken from a pile on the bank of the Pasig River. It had been quarried some time.

[b] Kept in a tightly stoppered bottle so as to retain quarry moisture, dried immediately at 100° when opened.

[c] Kept in a tightly stoppered bottle so as to retain quarry moisture. Not opened until ready to break. It was broken moist with quarry water.

[d] An old stone which had been used many years in a building. It showed marked signs of decay.

For purposes of comparison I have recalculated the results[8] of some Wisconsin building stones which are given below:

Table V.—*Transverse strength of Wisconsin building stone.*

Source.	Number of samples averaged.	Length.	Breadth.	Height.	Weight of load.	Modulus of rupture per square centimeter.
SANDSTONE.						
		Cm.	*Cm.*	*Cm.*	*Kilos.*	*Kilos.*
Babcock and Smith quarry	2	8.89	2.55	2.85	57.8	37.0
Bass Island Brownstone Co. quarry	2	8.89	2.45	2.65	49.4	41.8
C. and N. W. Ry. Co. quarry	6	10.16	2.58	2.62	83.0	71.3
Flag River brownstone quarry	2	17.78	2.78	2.80	25.6	31.3
Grover red sandstone quarry	1	7.62	2.70	2.43	35.8	25.5
Grover red sandstone quarry[a]	1	7.62	2.45	2.45	13.6	10.6
Prentice Brownstone Co. quarry	2	12.70	2.72	2.81	41.3	36.5
LIMESTONE.						
Bridgeport quarry	1	15.24	2.69	2.71	71.2	81.9
Story Bros. quarry	2	15.24	2.41	2.76	120.2	149.7
Marblehead L. and S. Co. quarry	1	15.24	2.73	2.73	227.3	255.4
Menominee Falls Co. quarry	1	15.24	2.77	2.62	185.5	222.9
Laurie Stone quarry	1	12.70	2.66	2.59	307.5	327.6
GRANITE.						
Montello Granite Co. quarry	2	10.16	2.53	2.75	335.2	266.8
New Hill O'Fair quarry	2	10.16	2.67	2.66	232.2	177.1

[a] Sample was wet.

The modulus of rupture of the tuff is not high, but it is not necessary that it should be since it is not used as caps and sills in heavy buildings. The necessity of having a high modulus of rupture was obviated in the large buildings, for example the Guadalupe church, by using stone of considerable thickness and by arching the doors and windows.

Durability.—The durability of a stone depends chiefly upon its ability to withstand the mechanical, physical, and chemical conditions to which it is exposed. The most important durability tests which aid in determining this are the specific gravity and porosity.

Specific gravity.—The method employed was to weigh the sample in air and then to weigh it, completely saturated with water, in water at a definite temperature and finally to divide the weight in air by the difference and correct for the difference in the specific gravity of water at the given temperature. It is realized that complete saturation is difficult to attain, but I think the method used is satisfactory. A cube of Guadalupe tuff was slowly (several hours were required) immersed in water and finally allowed to remain over night completely covered with water. The results have been computed in two ways, first, on the basis of the sample air-dried in my laboratory for eight months (July to March), and second, on the basis of the sample absolutely freed from interstitial water by heating in an air-bath at 110° for eight hours. The sample retained only 0.7 per cent interstitial water after being air-dried for eight months. The specific gravities (water at 4°=1) are as follows:

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[8] Buckley, E. R.: *Bull. Wis. Geol. & Nat. His. Sur.* (*Econ. Sr. 2*) (1898), **4**, 396.

I.	II.
1.895	1.907

Porosity.—To obtain this factor,[9] the weights of the dry and saturated stone were used. The sample was saturated as described above, the surface quickly dried by pressing in filter paper and the weight taken.

The difference in the weights was multiplied by the specific gravity 1.907 and the product added to the dry weight. The difference of the dry and saturated weights multiplied by the specific gravity divided by the above sum gives the actual pore space, compared with the volume of the sample tested, as 28 per cent.

Temperature changes.—The coefficient of expansion is a most important factor in the disintegration of rocks in many places. Alternate freezing and thawing and extreme heat in case of conflagration are the commonest causes of disintegration in northern countries. Rocks often contain grains of widely different coefficients of expansion and with change of temperature internal strain is produced which aids in the destruction of the rock. A porous rock is somewhat able to accommodate itself to such a strain. This volcanic tuff, as is true of all very porous stones, can not be used in a cold country because the absorbed water freezes and, breaking the bonds, causes the stone to crumble, but the uniform temperature of the Philippines favors the long life of a soft, porous stone.

Water upon freezing at 0° and under one atmosphere pressure expands about one-ninth of its volume. If the water is not allowed to expand it must remain liquid. James Thomson[10] calculated that the melting point of ice would be lowered by n 0.0075° for an increase of n atmospheres. W. Thomson[11] confirmed this calculation within a difference of 3 per cent by determining the melting point of ice at 8.1 and 16.8 atmospheres. M. Mousson[12] kept water liquid at −5° by greatly increasing the pressure and found that at a pressure of about 13,000 atmospheres, ice melted at −18° to −20°. Calculated from the data of Thomson the value for −20° would be but 2,666 atmospheres, about one-fifth the value obtained by Mousson. Assuming the smallest value, it is evident that there is no stone strong enough to resist the strain produced by the freezing of any considerable quantity of water within its pores.

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[9] Buckley, *loc. cit.*, 69.

In the Philippines the abundance of rain and the high humidity of the air keeps the stone moist during the greater part of the time. The action of the water is markedly twofold, as a solvent for mineral matter and as a solvent or carrier for the gases of the atmosphere. This tuff hardens rapidly after being exposed to the air and this change is undoubtedly hastened by the presence of moisture. Table III shows an increase of nearly 50 per cent in the tensile strength of Guadalupe stone which had been exposed for some time. Majayjay stone which had been exposed so long that it was considerably decayed, still had a tensile strength about equal to that of the newly quarried stone.

Cubic weight.—The cubic weight of this stone as it is taken from the quarry depends upon its specific gravity, porosity, and the water content. With uniform stone the only fluctuating quantity is the water content. Owing to the very large pore space and the heavy rains in the Philippine Islands we may expect this stone to absorb and give up water readily and its cubic weight to vary between the limits for the thoroughly air-dried sample and the saturated one, namely, 1,375 to 1,655 kilos per cubic meter (35.3 cubit feet).

The rate at which this stone gives up its water in dry storage is also an important factor in its transportation.

Cubes of different sizes were carefully saturated with water and suspended in the laboratory on a 1-centimeters-mesh wire net so that evaporation could take place equally from all surfaces. The tests were begun on March 23, 1908. The data and the results are as follows:

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[10] *Trans. Roy. Soc.* Edinburg (1849), **16,** 575; *Camb. and Dubl. Math. J.* (1850) **5,** 248; *Ann. d. Chim.* (1852), **35,** 376.

[11] *Phil. Mag.* (3), (1850), **37,** 126.

[12] *Pogg. Ann.* (1858), **105,** 172; *Ann. Chim. et Phys.* (3), (1859), **56,** 252.

TABLE VI.—*The rate at which tuff dries in the air.*

Time of aëration.	Period of aëration.	Water referred to the dry stone in cubes of approximately—				Average temperature during period.	Average humidity during period.	Rainfall during period.
		2.5 cubic centimeters.	5 cubic centimeters.	10 cubic centimeters.	20 cubic centimeters.			
	Hours.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*°C.*	*Per cent.*	*mm.*
When saturated	0	35.31	35.07	35.52	35.35	----------	----------	----------
2½ hours	2½	32.05	33.60	34.79	----------	31.6	50.5	0
6½ hours	4	24.35	30.40	32.66	----------	32.5	49.7	0
22½ hours	16	3.89	19.33	28.55	----------	24.6	78.2	0
26½ hours	4	2.79	17.73	----------	----------	28.1	64.6	0
30½ hours	4	2.39	15.25	26.78	30.97	27.2	75.0	6.1
46½ hours	16	1.99	9.23	23.40	28.75	24.6	88.4	0.5
54½ hours	8	1.64	5.72	----------	----------	29.2	65.6	0
73 hours	18½	----------	2.91	16.13	25.84	24.1	75.2	0
94½ hours	21½	1.64	1.92	10.58	----------	26.5	66.6	0
107½ hours	13	----------	1.73	8.64	21.97	27.7	70.0	0
120½ hours	13	1.64	1.72	7.17	----------	25.1	81.1	0
169 hours	24½ 24	----------	----------	4.64	----------	27.1 26.0	75.7 87.7	0.1 58.0
216 hours	47	----------	----------	3.30	12.30	26.1	74.3	0
266 hours	50	----------	----------	2.54	9.22	27.1	65.3	0
288½ hours	22½	----------	1.68	2.34	----------	27.3	68.8	0
336½ hours	48	----------	----------	2.16	6.94	27.1	69.4	0
398 hours	61½	----------	----------	1.95	5.70	27.9	65.2	0
450 hours	52	----------	----------	1.92	4.59	28.3	63.6	0
495 hours	45	----------	----------	1.95	4.04	27.5	66.6	0
545 hours	50	----------	----------	----------	3.56	28.0	65.6	0
591 hours	46	----------	----------	----------	3.20	27.6	66.3	0
710 hours	119	----------	----------	----------	2.59	28.3	68.3	0
769 hours	59	----------	----------	----------	2.30	27.7	61.4	0
1,000 hours	231	----------	----------	----------	1.82	28.5	66.4	0
1,070 hours	70	----------	----------	----------	1.80	27.5	77.6	38.2
1,382 hours	312	----------	----------	1.94	1.75	28.1	78.0	84.2
After drying at 105° to 110° and cooling in a desiccator	----------	0.00	0.00	0.00	----------	----------	----------	----------

The foregoing data may be expressed in curves as follows:

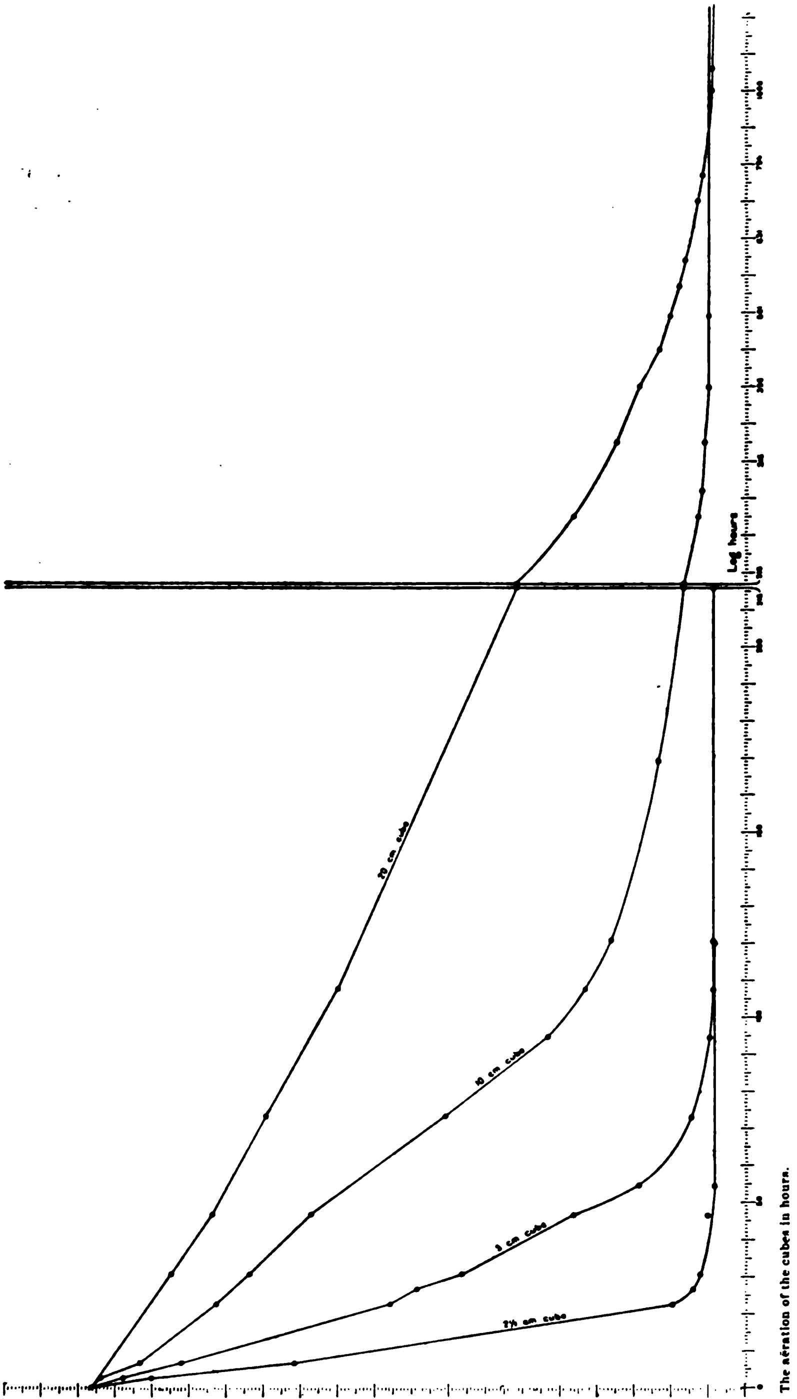

FIG. 1.

The irregularities in the curves can be directly accounted for by the variations in the humidity and the temperature of the air from day to day. The curves show this sample of tuff to be in equilibrium with the atmosphere when the latter contains about 1.75 per cent of loosely held water. All of this may be removed by drying at a temperature just above the boiling point of water, but the tuff quickly regains most of it when again exposed to atmospheric conditions. Upon resaturation the cubes absorbed enough water to return to the original saturation value.

If there were no other elements influencing the loss of water, the rate of evaporation from blocks should be directly proportional to the surface exposed, i. e., the curve expressing it would be a linear function of the latter; however, several other factors enter. The exposed surface of the cubes used bear to each other the relation 1, 4, 16, and 64. It will be noticed (fig. 1) that the cubes reach equilibrium with the atmosphere not in the above time ratio, but in approximately 36, 108, 324, and 972 hours, respectively, or a ratio of 1, 3, 9, and 27. The chief factor causing the differences in these ratios is capillarity and it is constant. Hence the following curve can be plotted, from which the time required for a cube of any size to dry may be directly read:

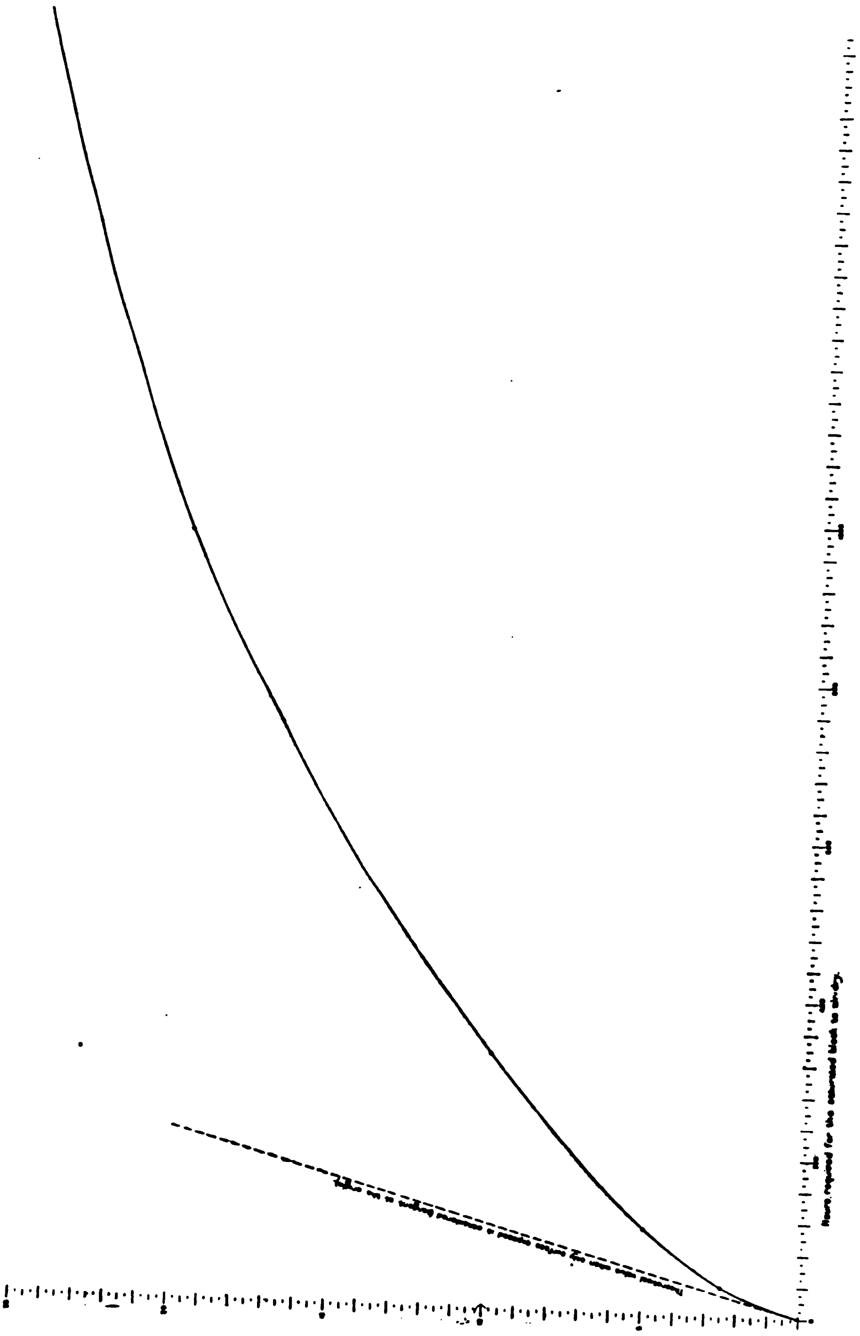

FIG. 2.

Variability.—These few tests show that physically the tuff occurring throughout the Philippines is very variable. When no attention is paid to its selection it may be good or extremely poor and this is why it has fallen into disrepute. With the selection of a good quarry, this stone should be valuable, especially because of its accessibility and the ease with which it is worked.

CHEMICAL EXAMINATION.

The chemical constitution of several samples of Philippine tuffs and their close relationship to the igneous rocks is shown by the following analyses:

TABLE VII.—*Analyses of Philippine tuffs and igneous rocks.*

[Figures give percentages.]

Source.	Tuff from—				Igneous rock from—			
	Manila.[a]	Guadalupe.		Majayjay.	Malaqui, Taal Volcano.[d]	Aroroy, Masbate.[e]	Canlaon Volcano.	
		a.[b]	b.[c]				North rim of new crater.	Southwest slope of old crater.
Silica (SiO_2)	56.84	56.55	59.27	57.26	53.81	58.14	53.69	55.97
Alumina (Al_2O_3)	18.46[f]	22.34[f]	17.06	16.95	19.69	17.93	18.00	20.85
Ferric oxide (Fe_2O_3)	0.75	1.87	2.16	7.55	8.16	5.46	9.11	6.26
Ferrous oxide (FeO)	2.51		2.61					
Lime (CaO)	4.78	4.74	3.37	3.56	7.73	7.63	8.64	7.92
Magnesia (MgO)	1.59	2.36	1.52	1.10	3.13	2.61	4.59	3.40
Soda (Na_2O)	4.12	2.38	2.49	1.64	3.64	4.08	3.07	3.52
Potash (K_2O)	2.72	2.84	3.63	1.86	2.19	2.16	1.63	2.48
Loss on ignition[g]	6.95	4.86	6.42	7.65	2.13	1.76	1.08	0.88
Water (H_2O) (below 105–110°)	1.76	2.51	1.34	1.43	0.24	0.10	0.31	0.33
Titanic oxide (TiO_2)	(h)	(h)	0.83	0.91	(h)	(h)	(h)	(h)
Manganese oxide (MnO)	trace.		trace.	0.23				
Total	100.48	100.44	100.70	100.14	100.72	99.87	100.12	100.61

[a] Equal portions of the three samples given in Table I were mixed thoroughly, pulverized, air-dried and analyzed.

[b] Sample collected in 1906.

[c] Sample collected in 1908.

[d] Average of two very closely agreeing independent samples, probably dolerite.

[e] Average of two very closely agreeing independent samples, probably andesite.

[f] Includes titanic oxide (TiO_2).

[g] Mostly water (H_2O) above 105–110°.

[h] Included in alumina.

CEMENT.

I first analyzed the Philippine tuff in the early part of 1907. Its composition is nearly the same as many of the clays and shales used for cement manufacture. Since then I have had hopes that it might be used as a cement material and have expended considerable effort in the attempt to use it for this purpose. In 1887 Le Chatelier[13] proposed the formula $x\ [(3CaO)SiO_2] + y\ [(3CaO)Al_2O_3]$ for Portland cement, but S. B. and W. B. Newberry[14] have shown that the formula $x\ [(3CaO)SiO_2] + y\ [(2CaO)Al_2O_3]$ produces a much better cement. Both of these formulæ are based on a more or less ideal condition of fluxing and there are cases where even the latter gives a percentage of lime in the finished product very much higher than that of the average Portland cement; however, it is valuable to the cement chemists as a limiting formula. Bleininger[15] has made a series of investigations from the results of which he concludes that "for the dry ground mixtures the formula $(2.8CaO)SiO_2,(2CaO)Al_2O_3$ is the safest." Several cement batches were made up with the sample of tuff from Manila according to the formula for Portland cement, calculated in such a way that after burning the percentage of lime would vary within the limits of good Portland cement. The materials were combined so that the finished product contained:

For each molecule of SiO_2, molecules of CaO resp. MgO, as follows:	And for each molecule of Al_2O_3 resp. Fe_2O_3, molecules of CaO resp. MgO, as follows:
2.8	2
2.6	2
2.4	2
2.2	2

I have not as yet been able to obtain a furnace temperature above 1,350° C and that is too low satisfactorily to burn a cement. All of the above mixtures when burned at this temperature disintegrated spontaneously on cooling, which is characteristic of the dicalcium silicate $(2CaO)SiO_2$[16] and indicates that the heat was not sufficient to fuse the other compounds of silica, alumina, lime and iron oxide which promote the union of silica and lime to form the tricalcium silicate $(3CaO)SiO_2$, which is the basis of hydraulic activity in Portland cement. In a small crucible over a blast lamp I prepared a cement from the ingredients limestone, clay, and shale which set well, but a sufficient quantity could not be obtained in this way to ascertain the physical constants. With this same method I could not produce a cement from the tuff cement batch, indicating that if cement can be produced from this material a still higher temperature is necessary.

Recently Howe[17] has shown that a cement of good quality can be produced from Panama rhyolite tuff, which is not very unlike that of the Philippine Islands in composition. The Panama materials used were coral, rhyolite tuff and clay of the following compositions. For purposes of comparison I also give some analyses of Philippine materials.

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[13] *Ann. des Mines* (1887), 11, 345.

[14] *J. Soc. Chem. Ind.* (1897), 16, 887.

[15] Bleininger, A. V., The Manufacture of Hydraulic Cements, *Geol. Sur. of Ohio* (1904) (4), 3, 236.

[16] Le Chatelier, *loc. cit.*

[17] *Econ. Geol.* (1907), 2, 655.

Component.	Panama cement materials.			Materials near Manila.		Analyses of Philippine limestones.				
	Coral.	Rhyolite tuff.	Clay.	Tuff[a] from Guadalupe.	Pasig clay.[b]	From Danao, Cebu coal fields.	From near Pilar, Capiz.	From the interior, Capiz near Dumalag.	From Romblon.	Average from military reservation drill holes Nos. 5 and 6, Batan Island.
SiO_2	0.89	60.98	49.91	57.68	50.51	0.36	0.72	0.21	0.10	0.97
Al_2O_3	0.32	15.86	15.48	16.60	20.20	0.18	0.51	0.17	0.17	0.56
Fe_2O_3	0.36	5.46	10.06	4.92	8.08		0.31	0.71		0.36
CaO	52.62	4.02	6.98	3.28	3.88	55.62	54.08	54.42	55.23	53.86
MgO	0.38	1.79	2.27	1.48	2.48	--------	0.99	0.41	0.45	0.19
Loss on ignition	43.50	10.44	12.92	10.44	12.92	43.67	43.98	43.84	43.80	43.47

[a] Recalculated to the same loss on ignition as the Panama tuff.

[b] Recalculated to the same loss on ignition as the Panama clay.

It will be seen that the Panama coral is a fairly pure calcium carbonate low in magnesia, ideal for the manufacture of cement. The analyses of several samples of Philippine limestones show them to be even purer than the Panama sample. Limestone occurs abundantly throughout the whole Archipelago and is uniformily remarkably pure.

From analyses giving the composition of the cement clinker, the Panama materials were mixed in the following proportions and gave the following data and results for the final product:

Ingredients.	Parts coral.	Parts clay	Parts tuff.	Fineness of grinding in per cent.			Tensile strength of briquettes in kilos per square centimeter.[a]								
							Neat.					Sand (3:1).			
				No. 50 sieve.	No. 100 sieve.	No. 200 sieve.	24 hours.	7 days.	28 days.	3 months.	6 months.	7 days.	28 days.	3 months.	6 months.
Coral-clay	2.88	1	-----	100	98	90.3	16.7	44.5	50.6	51.7	57.8	14.4	21.2	25.7	27.7
Coral-tuff	3.30	-----	1	100	99	93.3	14.8	39.4	44.7	43.8	47.7	15.9	21.9	27.6	30.0
Coral-clay tuff	-----	-----	-----	100	95	88.6	20.3	43.1	51.6	47.6	-----	12.2	21.2	22.4	------

[a] One kilogram per square centimeter = 14.22 pounds per square inch.

It is interesting in the above table to note that the coral-tuff cement gives the strongest sand mortar.

The laboratory is now preparing to install a small rotary cement kiln and when this is completed further experiments will be carried on in this direction.

ILLUSTRATIONS.

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FIG. 1. (In text.) Curve showing the rate at which blocks of tuff give up their water in dry storage........ 401

2. (In text.) Curve from which the time required for a saturated cube of tuff of any size to dry may be directly read........ 403

EDITORIAL.

THE EFFECT OF LITSEA CHINENSIS ON THE HARDENING OF LIME MORTAR.

The leaves of the plant known to the Tagalogs as *puso-puso* (*Litsea chinensis* Lam.) have long been in favor with native masons for use in making mortars. Their present method of treating the leaves of the *puso-puso* for this purpose is to beat the fresh leaves into a pulp, adding water until the mixture is a pale green. This is rather sticky and becomes more so as it ferments. After it is thus prepared it is allowed to stand and ferment for from twelve to eighteen hours, when it is used with native lime.

Undoubtedly these leaves have been employed for this purpose for a long time as Blanco[1] tells us that *puso-puso* is well known in the Philippines, the leaves when infused in water for six or eight hours forming a mucilaginous substance, they being cut into small pieces with a knife and triturated very well before being put into the water. When the decoction is mixed with lime and sand it is stated that a very strong mortar is made which is said to be almost impermeable to rain.

The *puso-puso* is a tree 7 to 9 meters high with a very hard wood. It is a species widely distributed from southern (tropical) Asia to Malaya.

Governor Sandiko, of Bulacan Province, reports that the native masons make their cement of lime 30 parts, sand 60 and melaza 1 part; the water used being the *puso-puso* juice prepared as above described.

Mr. Warner, of the Bureau of Supply, using the *puso-puso* decoction and comparing its results with those obtained with lime and sand mixed with water alone obtained the following table. In all the tests 18¼ per cent of water, respectively, *puso-puso* solutions were used. The tensile strengths are as follows:

	Time of set.			Average.		
	One month.	Two months.	Three months.	One month.	Two months.	Three months.
Lime-sand-water	38	60	88	36¾	60¾	88¼
	37	62	90			
	37	60	87			
	35	61	88			
Lime-sand-melaza-puso-puso juice	48	53	77	49⅖	56⅕	82⅕
	50	55	82			
	50	56	81			
	49	61	90			
	50	56	81			

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[1] Blanco, Flora de Filipinas, 2d ed. (1845), 566.

The above experiments show that *puso-puso* and (melaza) increases the initial rapidity of hardening, but the indications are that in the final set the tensile strength is the same or somewhat less than when water is used alone.

In recent years tests of the influence of a great many indifferent substances have been made on the hardening of mortar with small positive or negative results.

Parsons and Porter[2] experimenting with Portland cement found that the addition of sugar or molasses delayed the setting of the mortar, the retardation being greater when molasses was used, but when certain proportions were not exceeded, the strength of the mixture was slightly greater than that of the pure cement. Sugar apparently has no chemical action on mortars. The variation of the binding power is due more to mechanical causes and probably favors or retards the chemical reactions involved. Rohland[3] concludes that the hardening of cement is not due to the formation of chemical compounds, but to a specific action of colloids, and perhaps the same might be said of lime mortar. I believe that in the final equilibrium few, if any, foreign bodies have a positive influence.

The above-described use of *puso-puso* juice appears to give no explanation of the extreme hardness of some of the old mortars. In general the hardening of lime mortar depends on the chemical reaction

$$Ca(OH)_2+CO_2 \rightarrow CaCO_3+H_2O.$$

This reaction really exhibits two phases, namely,

1. $Ca(OH)_2 \rightarrow CaO+H_2O$ and
2. $CaO+CO_2 \rightarrow CaCO_3$.

The velocity of the reaction is extremely slow, requiring months, years, and in some cases even hundreds of years to complete it. The difficulty with which gases penetrate solid walls is shown by the fact that reënforcing steel embedded in concrete will remain free from rust. Recently in tearing down a one-story building erected in 1902 at New Brighton, Staten Island, all steel reënforcements were found in perfect preservation excepting in few cases where they were allowed to come closer than three-fourths inch to the surface.[4] Uncombined calcium hydroxide has been found in mortar inclosed between very compact stones after they had been in place three hundred years. In the light of these facts the explanation of the superior quality of the old lime mortars found in various places is probably that the porous stone so generally used renders it possible for the carbon dioxide of the air to enter the interior parts of the massive masonry and so to hasten the equilibrium of the hardening reaction.

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[2] *Dingler's Polyt. Journ.* (1889), **271**, 268; *J. Soc. Chem. Ind.* (1889), **8**, 545.

[3] *Ztschr. f. Elektrochem.* (1907), **13**, 11.

[4] Turner, H. C. *Eng. News* (1908), **59**, 75; Anon. *Iron Age* (1908), **81**, 348.

ALVIN J. COX.

PROPRIETARY MEDICINES IN THE ORIENT.

The drugs inspection under the Philippine "Food and Drugs Act of May 18, 1907" is revealing many illegalities and peculiarities in the proprietary medicines of the Orient.

The Chinese medicines offered at the various ports for entry into the Philippine Islands are for the most part composed of pastes and powder manufactured from the herbs and animal products. Sea horses are caught in large number, dried, powdered, and compounded into medicines. The most abundant species is *Gasterotokeus biaculeatus* (Bloch); others are *Hippocampus kuda* Bleeker and *H. aterrimus* Jordan and Snyder. Other medicines are supposed to be manufactured from various parts of tortoises and stags.

The advertising literature, in Chinese, accompanying an invoice of pills states, "These pills are prepared from the best ginseng and deer's horn obtainable in this country," and recommends their use for all pains having neuralgic origin, rheumatism, liver and intestinal diseases, nervous exhaustion, overstudy and sleeplessness. Another variety of pills was labeled with the modest statement, "These pills are used as a tonic in the treatment of all diseases occurring among both sexes and all ages. For the healthy they are especially useful as a preventive in contracting disease." Then follows an enumeration of the ailments for which the pills are especially adapted, among which may be mentioned, general debility from overwork, alcohol, sleeplessness, rheumatic pains, toothache, headache, pain in the lumbar regions, heartburn, nausea, vomiting, loss of appetite, swelling of glands, and œdema of legs, face or abdomen. Many Chinese "medicinal beverages" are offered for entry at this port. One, labeled as a cure for rheumatism and dropsy and a tonic for lungs and liver, owed its effect to an alcoholic content of 50 per cent.

The usual varieties of Chinese pills containing morphine and opium are constantly met masquerading under various names and false statements as to their character and composition. One shipment of small, black pills, advertised and labeled as a cure for the opium habit was found to contain a large percentage of morphine.

While a large proportion of the Chinese medicines are of the proprietary class the patent medicine business of the Orient is by no means confined to the Chinese. Some establishments in this part of the world under the control of foreigners, place upon the market preparations which are in many cases more reprehensible in their composition and in the character of their advertising than the medicines manufactured by the Chinese. Proprietary preparations from Japan, United States, France, Spain, Holland, Germany, and some other countries are also to be found upon the local markets. Among those which have been found to be in violation of the "Food and Drugs Act" the following are typical examples.

A Spanish stomach tonic and a Japanese "injection" were both found to contain cocaine. A Spanish pectoral paste contained heroin and a "cholera elixir" was composed almost entirely of morphine and chloral hydrate. Japanese "brain pills" were found to owe their effect to the usual quantity of acetanilid. A widely advertised "dysentery cure" much used among the foreign element in the Orient was found to contain calcium carbonate 90.7, calcium phosphate 3.7, organic matter 3.6 and water 2.0 per cent, and is reputed to be either ground cuttlefish bone or ground oyster shells. Two bottles of liquid, shipped by mail, and purporting to be a physician's prescription, were found to be concentrated aqueous solutions of morphine sulphate.

Another preparation which "works miracles with every one that makes use of it, and the Grace of the Omnipotent God is experienced in it to admiration" is recommended in the accompanying advertising matter as a cure for stones in the bladder, bruises in the hands or feet, black and blue spots, thickness of blood, all kinds of fevers, asthma, liver troubles, hysterical pains, dropsy, the French disease, worms, palpitation of the heart, headache, burns, colic, and if put in the eyes "it will make you so strong sighted that you need not use spectacles until the age of 70 or 80 years, thus preserving the sight." Analysis shows the substance to be a fish liver oil.

The Narcotic Drug Law (Act No. 1761 of the Philippine Commission, October 10, 1907) so restricts the use of opium, cocaine, alpha and beta eucaine that many proprietary medicines and preparations are denied entry to the Philippine Islands.

H. D. GIBBS.

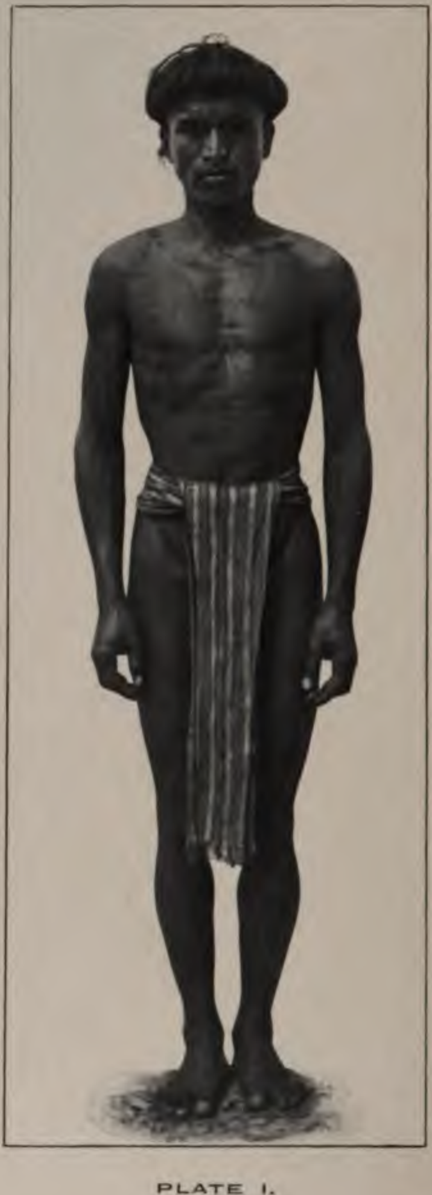

PLATE I.

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THE BENGUET IGOROTS. A SOMATOLOGIC STUDY OF THE LIVE FOLK OF BENGUET AND LEPANTO-BONTOC.

By ROBERT BENNETT BEAN.

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INTRODUCTION.

During the intersessional vacation of the Medical School in the year 1908, I spent two months at Baguio, the capital of Benguet Province, in studying the physical characters of the natives. No casual observer would expect to find white people inside of brown skins, but I found European types among the Igorots. (Plate I.) Trips were made to Atok, Tublay, and Capangan with parties under the direction of William H. Pack, governor of Benguet Province, to whom credit and thanks are tendered for his kindly coöperation in the work and his assistance in establishing the good will of the natives. Dean C. Worcester, Secretary of the Interior, also has my sincere gratitude for enabling me to carry through the work and for his many personal favors during its progress. I made excursions to points near Baguio from time to time, and obtained a few additional measurements at the Benguet Sanitarium and among the camps of laborers located in the vicinity of the town.

Benguet Province is situated in the central part of northern Luzon; Baguio, the capital, being somewhat less than 300 kilometers due north of Manila and about 30 kilometers east of the seacoast. The mountains of Benguet form a part of the *Cordillera Central del Norte* of the island, the most inaccessible portions of which lie in the north of the province and in Lepanto-Bontoc. Baguio lies at an altitude of 1,500 meters above sea level. It has a temperate climate and is located among pine hills on an irregular plateau southwest of the center of the province at the terminus of one of the most remarkable highways of the world. The latter is to a large extent carved out of solid rock and in many places the deep cañon of the Bued River is crossed by suspension bridges. The plateau on which Baguio is located rises northward along the west of the province in the form of a group of rugged mountains intersected by small streams that cut their way through narrow gorges to Lingayen Gulf and the China Sea, passing through Pangasinan as well as Union Provinces, the latter inhabited by Ilocanos, one of the most thrifty and energetic people of the Philippines, and great colonizers. The Ilocanos form the littoral population of the west coast of northern Luzon and have penetrated the mountains to some extent. The eastern part of the province from its extreme northern end to its southern limit is drained by the tributaries of the Agno River, beyond which are mountains separating it from the Province of Nueva Viscaya. The Province of Benguet is thus divided into mountain and valley, or highland and lowland. The entire province is practically inaccessible, except over the Benguet Road, over the Naguilan trail from San Fernando, Union, or the trail from Aringay, Province of Union. The rivers that pass out of the province are filled with water during part of the year; their beds are rough, the sides precipitous and the mountains steep and rugged, so that both mountains and rivers form very difficult ways of entry. The present governor is rapidly constructing trails in the mountains with a grade of from 3 to 5 per cent, the most audacious of these is nearing completion and will connect Benguet with the Province of Lepanto-Bontoc.

The inhabitants of this isolated region could have arrived only by crossing high and rugged mountains, or by picking their way along the beds of the rivers during the dry season. Whether they came of their own accord or were forced from the lowlands by other peoples may never be known. I believe the Igorots pushed into the mountains as bold pioneers in much the same way that the Puritan, the Scotch-Irish and the Cavalier crossed the Appalachians and settled the western part of the United States. They probably exterminated or absorbed any previous inhabitants and have built for themselves enduring monuments in their rock-ribbed and terraced rice paddies, and in the rock shelters for their dead. Their muscular development is phenomenal (19, 70,) and would put to shame the best American athletes. Their laws and customs are founded on justice and equity, and "an eye for an eye and a tooth for a tooth" is often carried out to the letter. Civilization has not yet greatly affected the Igorots and they are being protected from its evil influences as carefully as sedulous officials can protect them. They are one of the few uncivilized communities that civilization has touched yet not defiled.

The people of Atoc, in the western part of the province are a representative group of Igorots. Atoc is a bold point that juts out from the surrounding mountains at an altitude of 2,000 meters above sea level, and its precipitous sides furnish an almost impassible barrier against attack. The inhabitants of this region were the last of the Benguet Igorots to come under the jurisdiction of the United States of America, and it was only by superior force of arms that they finally submitted. They live on their rocky fortress, work the paddy fields of the valleys below, and return to their stronghold at night. They are a self-reliant and progressive people, with sound judgment and wise deliberation in their councils. The administration of their affairs is in their own hands under the guidance of the governor of the province. Their chief *baknon* (old man) has already roofed his house with galvanized iron for protection from the tremendous downpours of rain which are so frequent in this region, and others are following his example.

Men and women are on practically an equal footing. The men work away from home for means to provide food, shelter, and draft animals (for working the paddy fields), and when at home the men care for the children. The women work at home raising the small crops (*camotes*, coffee, etc.), prepare the food, and assist the men in the transportation of surplus products to distant markets over steep mountain trails, acting with the men as common carriers. The women also have a voice in the councils and often exercise a controlling influence. The life of the Igorots is an existence of ideal sexual equality in many respects, and civilized nations might profit by their example, for they impressed me as a remarkably contented and cheerful people.

However, the purpose of this article is not to present the moral qualities, but the physical characters of the Igorots. Observations and measurements were made of 104 adult males (16+ years), 10 adult females, and 30 boys between the ages of 5 and 15 years inclusive. I also measured a number of Japanese, Chinese, Ilocanos, and Tagalogs, but these data will be reserved to be presented in later papers on the various Filipino peoples. Four groups will be considered in detail with each observation or measurement. The nativity of the four groups is: Lepanto-Bontoc [15], mountains of western Benguet [73], the Agno River valley [30], and Baguio and vicinity [27]. Fourteen of the Lepanto-Bontoc Igorots are adult males, and 1 is a boy. Forty-six of the mountain Igorots are adult males, 10 are adult females, and the remainder are boys. Twenty-two from the valleys and 22 from Baguio and vicinity are adult males, the remainder boys. (Table I.)

METHODS EMPLOYED.

The body parts are measured from the ground up by means of a graduated vertical rod with a sliding horizontal pointer. Other measurements are made with sliding calipers (*compass d'appaisseur*-Colin). Lead electric fuse wire is used in taking head outlines, a hinged brass bar is employed to measure the facial index, and general descriptions are given of hair, brows, eyes, ears, nose, and skin, with occasional sketches.

Measurements and observations are made on the naked body of each individual, except the women, the usual breech clout not interfering at all. Some difficulty is experienced in obtaining one measurement, that of the superior extremity of the great trochanter of the femur, due to the solidity and rigidity of the hip muscles as the individual stands in the erect posture.

My measurements of the Igorots follow the personal instructions which I received from Professor Manouvrier in Paris during the summer of 1906, and I wish at this time to express my gratitude for the painstaking care exercised by him through the course of my training. The methods employed have been used by me during the past two years, and as they will apply to future work on the natives of the Philippine Islands, a brief résumé of the most important is inserted here.

The individual should stand in the position of a soldier(67). Projections are then made with the anthropometer as follows, using the level of the soles of the feet as the base:

HEIGHTS.

1. *Body height.*—Allow the beam to fall with a click on the top of the head (*vertex*).
2. *Ear height.*—The beam should point into the external auditory meatus (*meatus acusticus externus*).
3. *Chin height.*—The point at lower edge of mandibular-symphysis (*protuberantia mentalis*).
4. *Sternum.*—Press down firmly in the suprasternal notch (*incisura jugularis*).
5. *Umbilicus.*—The level of its middle.
6. *Pubis.*—The superior border of pubic hair. (I use the actual level of the pubic spine [*tuberculum pubicum*]).
7. *Acromion.*—The level of its outer tip.
8. *The elbow* (*cubitus*).—The level of the joint furrow in the flesh, at the head of the radius (*capitulum radii*).
9. *Wrist* (*carpus*).—The level of the lower extremity of the styloid process (*processus styloidus*) of the radius.
10. *Tip of middle finger* (*digitus medius*) with hand extended.
11. *Trochanter.*—Press extremely hard on the upper end of the femur (*trochanter major*).
12. *Knee* (*genu*).—The line in the rear on the skin passing exactly through the joint at the upper outer end of the tibia (*condylus lateralis*).

BREADTHS.

(*Made with triple elbow calipers.*)

1. *Shoulder.*—Press hard on the outer tips of the acromion processes.
2. *Hip.*—The outer lips of the iliac crests (*crista iliaca*).
3. *Thigh.*—The outer part of the trochanter (*trochanter major*).
4. *Pelvis.*—From the anterior superior edge of the symphysis to the diamond-shaped depression in the back, over the lumbar region.

The masterful work of Rudolph Martin (*"Die Inlandstämme der Malayischen Halbinsel"* (25)) is freely utilized in the course of the present study because of the complete presentation in tabular form of the results of recent investigators regarding the people associated with eastern Asia.

The present article is divided into eight parts the last three of which form a summary; these parts are as follows:

I, Stature; II, Body Parts; III, Head Form; IV, Physiognomy; V, Descriptive Characters; VI, Somatologic Race Types; VII, Three Selected Types; VIII, Supplementary Theory of Heredity.

I. STATURE.

The Igorots are a people of small stature (below 160 centimeters) although many individuals are above the average and some are tall. (Table III.) The average or mean height of 104 adult males and 10 adult females is 154.0 and 146.7 centimeters, respectively.

Further analysis reveals the fact that these groups are not homogeneous. Only 60 per cent of the adult males are between the height of 150 and 162 centimeters, a wide range for so small a number of individuals. The mode or height of greatest frequency (hence the fashion) is 150 centimeters, although there is only one less individual at 152, 154, and 156 centimeters respectively. The median (which has an equal number of individuals above and below it) is 153 centimeters. The minimum is 141 centimeters, and the maximum is 170 centimeters. There is an even distribution of individuals between 148 and 158 centimeters; there are 25 above 158 and 11 below 148 centimeters. (Table II.) A curve constructed from the number of individuals at the various heights represented by ordinates and abscissæ would not be a normal Gaussian curve, but would be platykurtic (flat-topped (74)) (45) with a tendency toward tallness, indicating great variability, and more than one type of man.

The mean height of 14 Bontoc Igorots is 158.6 centimeters. One is only 148 centimeters high, one about 156, and 7 are about 164 centimeters. The three groups are significant when considered in connection with similar ones from the highland and lowland regions.

The mean height of 46 adult male Igorots of the highland region is 154.9 centimeters, the minimum is 142, and the maximum is 170. The height is less than that of the Bontoc Igorots, and the variability is greater, but the height is more than that of the lowland Igorots.

The mean height of 22 adult males from the valley is 153.6 centimeters. The smallest is from Trinidad in the open country, and the two tallest are from Buguias, which is in the northern end of the province, near Lepanto-Bontoc. The mean height of the 5 men from Buguias is 155.2 centimeters, while that of the 5 from Trinidad is only 152 centimeters. This would suggest that there is an element of small people at Trinidad. The 5 men from Baguio and the 5 from Kabayan have a mean height of 156.8 and 151.2 centimeters respectively, which would indicate the same for Kabayan. However, five individuals are not enough from which to determine a mean height, although the measurements do indicate the characteristics of a part of the population.

The mean height of 22 adult males from Baguio and vicinity is 149.1 centimeters. Their nativity was not ascertained for lack of an interpreter, but many of these probably come from Trinidad. For this reason the group is not characteristic for the whole province, but for Trinidad, Baguio and vicinity.

The individuals of each of the three groups, Lepanto-Bontoc, Highland, and Lowland, may be divided into those of small, those of intermediate, and those of great height. The height of the small individuals varies around 148 centimeters (*cf.* Negrito); that of the large individuals around 165 centimeters (*cf.* European); and the height of the greatest number of individuals is about 154 centimeters (*cf.* Malay). The people of Atoc are slightly above and the people of Baguio and vicinity are slightly below the figures given, but the three groups are definitely represented there as elsewhere. The conclusion from the examination of the height alone is that at least three groups of people make up the Igorot population. (Table II.)

The mean height varies directly with the altitude, but probably this variation is not due to the effects of mountain or river, but to the difference in type of the individuals making up the population. The accessible parts have been influenced by infusions of blood from outside of the Province of Benguet, whereas the inhabitants of the inaccessible regions are more like the original type. However, it is possible that outsiders of a bold and daring nature penetrated to the most inaccessible regions, and these may have been tall individuals who increased the average height of the community by their presence and by their progeny.

The mean height of the Igorots is 3.6 centimeters greater than that given by Martin(26) for the inhabitants of the Malay Peninsula. It is also greater than that of the Veddahs of Ceylon (Sarasin), but it is less than that of the Annamites(14), the Japanese, the Koreans, the Javanese and various other peoples in the region adjoining eastern Asia.

Sexual differences in height can not be fairly stated because so few women were measured, but it may be of interest to note them.

The mean height of the female Igorots is 146.7 centimeters, the minimum 135 centimeters and the maximum 154 centimeters. The mode is 146 centimeters and the median 145 centimeters. The female height throughout the world is 7 per cent less than the male, or in other words the female is 93 per cent of the male height(27). Therefore, since the mean height of the Igorot women should be only 144.1 centimeters they are proportionately taller than the men.

STATURE AND RACE.(50)

Although local conditions acting on the same people for many thousand years may effect a change in stature, yet it remains true that stature is a potent factor in race differentiation. Food and nutrition play a part in determining this characteristic, and artificial selection is at work in modern social life, tall individuals being selected in marriage because goodly stature in youth implies a bountiful store of vitality. Occupation and habitat may influence it in the individual, but this is not transmitted to the offspring. City life reduces stature, but attracts tall men, so that the one balances the other. The tall, hardy pioneer survives in the mountain, but poor nutriment causes a decrease in height; hence a similar balance is found there. However, these influences act only on the individual and if they become hereditary it must be after countless generations.

Racial differences in stature are characteristic and persistent. The Malays are everywhere inclined to be short, and the Polynesians are inclined to tallness. The Scotch are the tallest people of Europe, the southern Italians are almost dwarfs; the first live in the mountains and the latter inhabit the coast. The Adriatic has a body of very tall people along its northern borders, but the mountains of middle Europe are inhabited by short individuals. The Teutonic people have retained their height wherever they have gone. The inhabitants along the shores of Brittany, which were ravaged so fiercely by these northern barbarians, are taller than the people of the interior. The valleys south of Germany (Tyrol) have been infiltrated by the tall invader, leaving the short man in the mountains.

Many other instances could be cited to prove that stature is incident to race, but as the weight of evidence is in favor of this, the burden of proof rests with the opposition; as well argue that long heads are due to mountain height, because long-headed Igorots are found high up in the mountains, as to say that short stature is due to high altitude, or *vice versâ.* However, it may be that stature, like so many other characters, becomes altered by environment in the life of a single individual, but the altered condition is not transmitted, until, through countless generations in the same environment, the altered character becomes fixed and inheritable.

The stature of the Igorots then, is probably a racial character, and not a local condition.

STATURE AND AGE.

The stature of the boys as contrasted with that of the adult males, and the relation of growth to age deserve consideration. The ages which I have given are not exact in every instance, because age is determined by the number of rice harvests since the birth of the individual, but as the rice harvest is annual, this method of record is fairly accurate.

The individuals are arranged in small groups from the age of 5 to 20 years, and in larger groups above this age. (Table IV.) The mean stature increases about 5 centimeters per year up to the age of 16, when the adult height is apparently reached, although a slightly greater height is found between 20 and 30. The height at 18 and 19 is less than that at 16 and 17, but the small number of individuals at 18 and 19 may account for this. For the same reason, the great height of 5 men above the age of 50 years, and that of the boys from 5 to 10 years of age, are not fair estimates.

The two most significant features of the relation of height to age are the apparently early maturity of the Igorots and their aquisition of maximum height at an earlier age than Europeans. This agrees with the conclusions of Martin(28), regarding the inhabitants of the Malay Peninsula. Hastings(17) has presented the average height for each age of 8,245 typical male American school children, his figures compared with the height of the Igorots shows a difference of about 10 centimeters in favor of the American children at each age up to 17, and a further increase of about 10 centimeters to the age of 19, when the American boy is 20 centimeters taller than the Igorot. The actual height as well as the growth of the American children conforms well with Topinard's deductions from measurements of 1,104,841 Europeans(61). The age in the latter instance is carried beyond 30 and the greatest height is found to be between 30 and 40 years. There is an annual increment in height up to 35 years(60). This increment decreases during the period of from 1 to 5 years, makes a sudden slight increase at 6, remains stationary from 7 to 10, increases progressively from 11 to 16, decreases suddenly at 17 and slowly thereafter to the age of 35, when the increase in height ceases.

The growth of the Igorots is similar to this.

The stature increases steadily from 10 to 17 years, there is a decrease to the age of 20, then an increase to the maximum between 20 and 30. After 30 the height decreases slightly to the age of 50.

The relative height increment of the Igorot boy is not unlike that of the European girl,[1] because the annual increment decreases in both from the age of 13 to 19(60).

DISCUSSION OF STATURE.

In conclusion it may be said that the growth of the Igorot is similar to that of the European, but that it is more rapid. The Igorot male is as well developed at the age of 16 years, as the European at 18. The maximum height of the Igorot is reached between 20 and 30, that of the European ten years later. The relative growth of the Igorot boy is intermediate between that of the European girl and the European boy. The height of the different groups of Igorots(73) varies directly with the altitude and inaccessibility of their location, but the rate of growth, the time of maturity and the actual height are probably characteristic of the stock and not due to environment.

The stature of the adult male Igorots is represented by a curve which is seen to be irregular. (Fig. 1.) With only 104 individuals some irregularities in the curve might be expected, which would be smoothed if 1,000 had been measured, but evidence indicates that irregularities in a curve of 100 individuals mean a diversity in type due to previous mix-

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[1] European is used in the sense of the white or Caucasian.

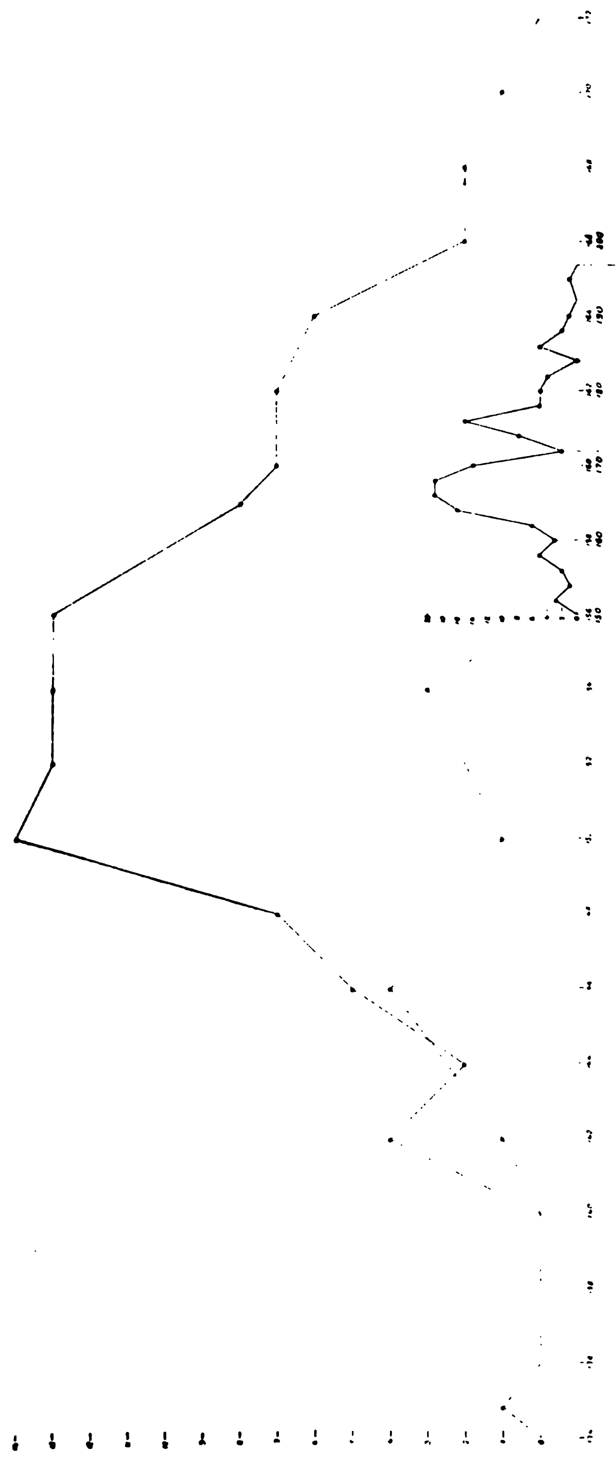

FIG. 1.—The large vertical column of numbers 0–14, represents the absolute number of Igorots, and the large horizontal row of numbers, 134–172, the stature of the Igorots.

The vertical column of small heavy numbers, 0–20, represents the absolute number of male negroes and the lower row of heavy horizontal numbers, 150–200, the stature of the male negroes.

Large scale and figure = { —— male Igorots.
female Igorots.

Small scale and figure = —— male negroes

A = Hottentot, Bushman, Negrito.
B = Guinea Coast negro.
C = Mulatto.
D = Kaffir negro.

ing of types. This meaning is obscured by constructing a curve with 1,000 individuals from the same population.

Take for instance the height of about 150 negroes that I measured at the Johns Hopkins Hospital Dispensary in 1906. There is great irregularity in the curve, which has seven summits, as may be seen in the small figure in the chart. Each of the summits represents a group of negroes well recognized in the United States, and known to exist in about the proportion and with the height given. Pygmies are rare, Hottentots are not plentiful, and extremely tall negroes are seldom found. The Guinea Coast negro, the Kaffir and the mulatto make up the bulk of the negro population in America. With 1,000 or more individuals, the types as represented by the height would be obscured and only an average negro height would be the result. Topinard(62) classifies 48,282 negroes and mulattoes by height and arrives at a single result, to wit: The average of the American is the same as that of the African negroes, namely, 168.1 centimeters. This is a not insignificiant result in itself, but it leaves much to be desired in the classification of negro types. Much depends upon the selection of individuals, but in a random sample with no selection there should be no spurious types. There was no conscious selection of negroes or of Igorots, but every available individual was measured.

Three summits are evident in the curve of height for the female Igorots as well as for the males. The summit for tall women (160 centimeters) is considerably prolonged, while that for small ones is not. The interpretation of the curve would be as follows:

The large central portion represents the majority of the people, and this is the most frequent type. The two extremes of the curve represent a small and a tall people who have mixed with the others. The small people are few in number and have had slight influence in altering the type, while the tall ones are in greater numbers and have modified it considerably, causing the central part of the curve to be flat-topped by increasing the number of individuals with height above the mean. Reasoning from this premise we may conclude that the original stocks of Igorots had a mean height of about 150 centimeters or less, which is the same as that of the people of the inland part of the Malay Peninsula(26). Martin's curve, however, shows three summits for both males and females, and there is evidence of three peoples among his subjects, so one must search back of this for the primitive stock. Whatever that may have been, the influence of a tall people is evident, and this came at a remote time, when the tall people were present in great numbers. Later came the influence of the small people, which there is good reason to believe were the Negritos. The mean height of 10 male Negritos of the Philippines according to A. B. Meyers is 144.5 centimeters, with extremes of 140.1 and 150.5 centimeters respectively(29); Montano gives the mean height of 18 male Philippine Negritos as 148.5 centimeters; Deniker(14) presents 42 Aeta-Negritos with a mean height of 146.5; Keane(21) gives the mean height 147.3; and Reed(47) states that of 48 mixed Negritos to be 146.3 centimeters. The height of 4 adult male Igorots is 142 centimeters, and there are 32 below 150.5 centimeters. The height of 5 male adults is nearly 170, and 60 per cent are above 150 centimeters. It is easy to conceive that a few Negritos would become attached to the Igorots in their progressive conquest of the mountains, but it is not so easy to believe that a tall people has joined them in the Philippines to make up about one-third of their number. Stray refugees or adventurers may have come to them from time to time in their mountain fastnesses, as in the case of an Ilocano, 168 centimeters in height, who came to Atoc from Union Province at the age of 15 years, fought in the war parties of the chiefs and was accepted as one of them for his continual daring and bravery. He is taller than the average Igorot, but not above the height of three of those measured. The Spanish influence must be reckoned with because the Spaniards have been in contact with the Igorots for at least fifty years (?), although no individual measured showed any indication of the Spanish influence in physical characters. A few tall men added to the Igorots from time to time may have had a slight influence, but they could not have altered the average height materially; furthermore the inaccessible parts have the tallest individuals, and the Bontoc Igorots, the most inaccessible and remote, are the tallest of the Igorots.

II. PROPORTION OF THE BODY PARTS.

The measurements made on the living are necessarily more inaccurate than those upon the skeleton, but with proper precautions and great care they may be used as differential factors in the physical anthropology of a people.

UPPER EXTREMITY.

(*Extremitas superior.*)

The Igorots are essentially short-armed, although there are long-armed individuals and the several groups show differences in the absolute length as well as the relative length. The mean (absolute) length of the upper extremity of 104 adult males is 67.82 centimeters, which is less than that of any other related Malay peoples, except the Senoi group(30) in the Malay Peninsula, and it is little less than that of the Japanese. The length decreases progressively with locality and altitude from the highlands to the lowlands as may be illustrated by grouping to show the mode and the extremes:

Absolute length of upper extremity, in centimeters.

Group, sex and age.	40–49.	50–54.	55–59.	60–64.	65–69.	70–74.	75.	Total.
Bontoc					3	9	2	14
Highlands				5	26	15		46
Lowlands		1	2	12	22	7		44
Adult males		1	2	17	51	31	2	104
Women			2	5	3			10
Boys, 12 to 15		1	7	10	1			19
Boys, 10 to 12	1	1	2					7
Boys, 10 and less	3	2						5

The range of variation judged by the difference between the extremes, and the spread of the mode, is greater in the lowland than in the highland or Bontoc groups, which indicates greater diversity of type in the lowlands. Reasoning from this premise, the conclusion is that Igorots from the lowlands are more recently mixed than the people from the highlands or from Bontoc.

The variation of the upper extremity as expressed by the difference between minimum and maximum, is 31 per cent of the maximum length for the entire extremity, 21 per cent for the upper arm, 30 per cent for the forearm, and 40 per cent for the hand. The actual variation in centimeters is:

	Centimeters.
Entire extremity	23.1
Upper arm	7.4
Forearm	9.1
Hand	8.0

The upper arm which is least variable is therefore a better factor for testing type differences, and the greatest difference is found between the Lowland and Highland Igorots in this part. Its mean length for the Bontoc Igorots is 0.8 centimeter greater than that of the highland group, and 2.0 centimeters greater than that of the Igorots of the lowlands. The mode is 1 centimeter greater for the Bontoc Igorots than for the highland people and 4 centimeters greater than for those of the lowlands. (Tables V, VI, and VII.)

According to this standard and by the total length of the upper extremity, the Lowland Igorots correspond to the Senoi of Martin(31), the Highland and Bontoc Igorots to the remainder of the population of the Malay Peninsula, as this table indicates:

Mean lengths of upper extremity, in centimeters.

Group.	Entire extremity.		Arm minus hand.		Upper arm.		Forearm.		Hand.	
	Absolute.	Relative.	Absolute.	Relative.	Absolute.	Relative.	Absolute.	Relative.	Absolute.	Relative.
Senoi	66.7	43.1	50.5	32.3	28.0	18.1	21.3	13.8	16.8	10.9
Blandas	69.9	45.4	52.5	34.0	30.3	19.5	22.2	14.3	17.4	11.3
Malayen	71.8	45.9	53.1	34.0	30.4	19.1	22.2	13.8	18.2	11.4
Lowland	66.5	43.8	50.5	33.8	28.6	18.7	22.0	14.5	16.2	10.6
Highland	68.3	43.9	52.1	33.6	29.8	19.8	22.4	14.4	16.0	10.3
Bontoc	71.8	45.2	53.9	33.9	30.6	19.2	23.3	14.8	17.8	11.3
Igorot women	62.8	42.7	47.6	32.4	27.1	18.5	20.5	14.0	15.1	10.3

Martin's Senoi group is almost exactly the same as the Lowland Igorots in the absolute and relative length of the entire upper extremity, the upper arm and the hand, and in the absolute length of the arm minus hand, and the forearm. The Igorots from the lowlands have a relatively longer forearm, and a relatively longer arm minus hand than the Senoi.

Martin's groups of Blandas and Malayen are similar to the Highland and the Bontoc Igorots in every measurement, except that of the forearm (absolute and relative), wherein the Bontoc Igorots exceed all others. The relative forearm length of the Bontoc is 14.8 centimeters which is equal to that of certain Europeans, below that of other Europeans, and considerably less than that of the negro(34). It corresponds to the Menangkabau-Malayen and the southern Chinese of Hagen(33), and occupies a position midway between that of the Japanese and the South American Indian.

The relative upper arm length of the Highland Igorots, which is the same as that of the European (19.8 centimeters) is as great as that of any other people so far measured except the Sikh (20.1 centimeters) (33). The relative hand length of the Bontoc is also the same as that of the European, and the relative length of the entire upper extremity is but a trifle less. That of the parts of the upper extremity and of the entire upper extremity place the Bontoc Igorots nearer the European than are the Highland or Lowland Igorots, and the Highland are nearer than the Lowland. The hand of the Highland, and of the Lowland as well, is unlike the European, Chinese, or negro, because it is relatively shorter. It is the same as that of the Igorot women, but less than that of any other people except the Senoi of Martin.

The absolute and relative length of the entire upper extremity, and of each of its parts is slightly less for the women than for any group of men. The hands of the women and the men of the highland group, however, are exactly the same in relative length.

The ratio of the forearm to the upper arm, the so-called "brachial index," is important to establish the relationship of the Igorots to other people. This index is 76.2 for the adult male and 75.6 for the adult female Igorots. It is 76.9 for the Lowland, 75.2 for the Highland, and 75.1 for the Bontoc. The brachial index is an additional differentiating factor for the Lowland Igorots, placing them in the same class as the Senoi, while the highland and Bontoc groups in this factor, as in so many others, are more like the European. The brachial index of the living has been determined by many different methods, and by so many different authors, that divergent results are reached on the same people. For instance Sarasin found the index of the Veddahs to be 91.9, while Martin determined it to be 73.8(32); Weisbach gives for Germans an index of 83.5 and Teumin for the Russian Jews one of 72. As Martin remarks there is great need for a fundamental reform in the methods of measuring the living.

The brachial index on the skeleton is greater than on the living, and is given by Martin for Europeans as 72.5, for Negritos, 83, and for the Senoi, 78.9. On the living, Martin gives the Senoi, 76.0 and the Blandas, 73.2, which again places the Senoi and the Lowland in the same class, while the Bontocs are nearer the Blandas.

LOWER EXTREMITY.

(Extremitas inferior.)

The measurements of the parts of the lower extremity are more exact than those of the upper, because in the latter there may be unconscious and unnoticed shifting of the parts when the measurements are being made, whereas in the former there is greater stability because the parts are placed firmly on the ground. The height of the pubis taken from the pubic spine is more accurate than the height of the trochanter, because of the accessibility and the ease with which the spine is located, whereas the heavy fascia, muscles and ligaments over the trochanter interfere with exact work.

Parallel measurements for comparison indicate that the pubis is slightly lower than the trochanter in the Igorots, but this may be due to the heavy gluteal muscles and fascia lata occurring in these incessant mountain climbers.

Height of trochanter and pubic spine compared, in centimeters.

Group.	Number.	Trochanter.	Pubic spine.
Bontoc	14	82.0	81.9
Highland	46	79.9	77.9
Lowland	44	78.1	76.0
Total	104	79.4	77.6
Women	10	74.1	71.7

Here again as in the other measurements, the Bontoc is the greatest, the Lowland least in absolute length, and the highland group is between the two. These measurements represent the absolute length of the entire lower extremity, and a glance at the next table will show that the relative length follows slightly the absolute length. Again there is the similarity between the three groups of the Malay Peninsula(35) and the Igorots.

Length of lower extremity, in centimeters.

Group.	Number.	Entire.		Approximate height of ankle.	
		Absolute.	Relative.	Absolute.	Relative.
Bontoc	14	82.0	51.7	5.6	3.70
Highland	46	79.9	51.6	5.2	3.55
Lowland	44	78.1	51.5	5.1	3.50
Total	104	79.4	51.6	5.4	3.55
Women	10	74.1	50.5		

The lowland group again corresponds to the Senoi, the relative length of the Bontoc lower extremity is almost identical with that of the European, and is less than that of the negro, but considerably more than the Japanese.

The women have absolutely and relatively shorter legs than the men of the highlands, with whom they should always be compared, because they belong to that group.

The length of the leg-minus-foot is approximate because the ankle height was obtained on but thirteen Igorots. However, the average of even so small a number emphasizes a fact that I observed constantly, to wit: The distance from the internal condyle to the sole of the foot is so short that it could with difficulty be measured, especially where the surface of the ground on which the individuals stood was rugged. The ankle height is similar to the hand length, especially in so far as the shortness is more pronounced in the highland and lowland group than in the Bontoc.

Length of leg-minus-foot, in centimeters.

Group.	Number.	Absolute.	Relative.
Bontoc	14	76.4	48.0
Highland	46	74.7	48.1
Lowland	44	73.0	48.0
Total	104	74	48.1

The absolute length of the leg-minus-foot follows the stature closely, but the relative does not, since it is equal in all the groups.

The intermembral index may be calculated from this, comparing it with the arm-minus-hand, but a fairer consideration under the circumstances would be a comparison of the entire lower with the entire upper extremity. Both are given so that the intermembral-index may be compared with that for the inhabitants of the Malay Peninsula(36).

Intermembral index.

Group.	Number.	Arm-minus-hand-*vs.* leg-minus-foot.		Entire extremity, upper *vs.* lower.	
		Bean.	Martin.	Bean.	Martin.
Bontoc	14	70.6	Blandas 71.4	B. 87.5	Blandas 87.8
Highland	46	70.0	Besisi 70.1	H. 85.4	Malayen 85.1
Lowland	44	69.2	Senoi I. 69.7	L. 85.1	Senoi I. 84.1
Total	104	70.0		85.4	
Women	10			81.7	

The Igorots have relatively longer arms as a whole in proportion to their legs than the Malays of the peninsula, but there is a general concordance as usual, and a similarity exists especially between the lowlands and the Senoi. The arm of the women although 5 centimeters absolutely shorter than that of the men, is relatively to the leg, about as long.

For the parts of the lower extremity the absolute length of the upper leg (femur) is the difference between the height of the knee and the trochanter, and the absolute length of the lower leg (crus) is the difference between the height of the knee and ankle.

Length of the parts of the lower extremity, in centimeters.

Group.	Number.	Upper leg.		Lower leg.		Tibio-femoral index.	Stature.
		Absolute.	Relative.	Absolute.	Relative.		
Bontoc	14	39.4	24.9	36.9	23.3	93.6	158.6
Highland	46	38.3	24.8	36.3	23.4	94.7	154.9
Lowland	44	37.2	24.5	35.8	23.6	96.2	154.6
Total	104	38.0	24.7	36.0	23.4	94.7	154.0
Women	10	33.9	23.1				146.7

All the lengths show in general the same relation between the groups of the Malay Peninsula and those of the Igorots as the preceding measurements, except that the tibio-femoral index is from five to ten points higher for the Igorots. This corresponds to the crural index of Hagen(36) for the Malay and Melanesian people, which is 90.8 "*bei Alus,*" and 97.4 "*bei Neu-Mecklenburgern.*" The measurements are equal to those of the European and Japanese, and are less than all other related East Asiatic people except the Aino. The length of the upper leg, both absolute and relative, is less for the Igorot women than for any of the women from the Malay peninsula.

The relative length of the upper leg follows the absolute, as does the relative length of the entire lower extremity, so one may say the length of the lower extremity is determined by the length of the upper leg, which in its turn determines the stature of the individual. In other words the correlation of stature and length of upper leg is pronounced.

The same is not true of the lower leg, but rather the opposite. With absolute increase of length of the lower leg, the relative length decreases, so that the shortest Igorots have relatively the longest lower legs.

The tibio-femoral index presents this clearly. Compare it with the brachial index, and a striking similarity between forearm and lower leg is noticed. The shortest individuals have relatively the longest forearms and lower legs, while the longest individuals present the reverse.

It may be of interest in connection with the body parts to present the absolute dimensions of an Igorot and of a Senoi man(38). Selecting an individual Igorot with the same height as the Senoi man, the body parts correspond almost exactly, except that the hand of the Igorot is shorter and the upper arm longer than the same members of the Senoi. This is corroborative evidence in a special case of the general evidence obtained from the averages of the body parts. (Fig. 2.)

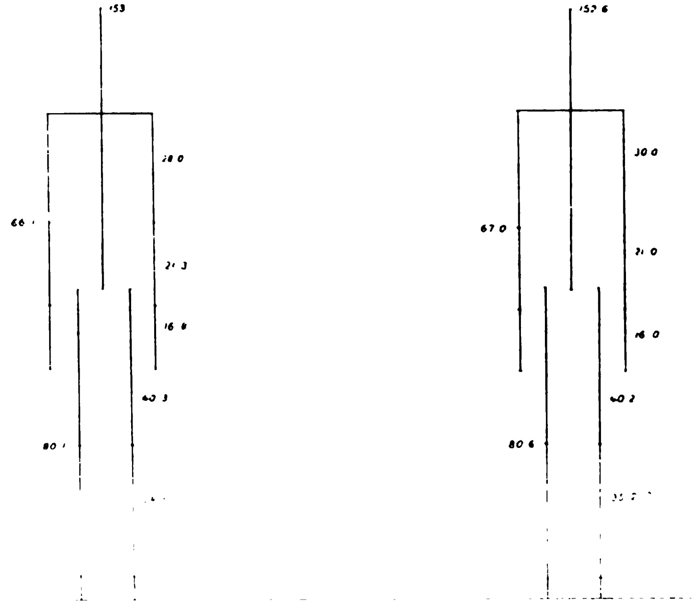

FIG. 2. Absolute length (in centimeters) of the body parts of a Senoi man (left figure) and an Igorot man (right figure).

The absolute and relative length of the extremities of the Igorots may be stated in contrast with similar measurements of other people.

The absolute length of the upper extremity of the Igorots is less than that of any other Eastern Asiatic people except the Senoi. The Northern Chinese have the greatest and the Japanese an intermediate length, or nearer the length of the Igorot arm.

The relative length of the upper extremity of the Igorots is less than that of the majority of the associated people. However, the Japanese and the Senoi have this relation shorter; the former the shortest of all, and the Veddahs and Ainos the longest, with the Europeans intermediate. The Igorots are midway between the Europeans and the Japanese.

The absolute length of the lower extremity of the Igorots is less than that of any other except the Japanese and Cochin Chinese, who have this dimension slightly less than the Igorots. The Japanese have the shortest and the negroes the longest legs of all people, while the Europeans are intermediate. The Aino and the Igorot are almost identical in leg length, and are midway between the Japanese and the European.

Martin's observations lead him to conclude that relative leg length and absolute leg length follow each other closely, in which I agree with him. The relative leg length of the Igorot is slightly nearer the European standard, but otherwise corresponds to the absolute leg length.

SHOULDER-HIP-PELVIS.

The shoulder width (acromian), and the width of the hips (iliac) may be contrasted and compared with the height, to determine relationships and differences.

Relation of the (iliac) width of the hips to the (acromian) width of the shoulders.

Group.	Number.	Shoulder.		Hip (coxa).		Relative hip shoulder breadth.	Pelvis.	
		Absolute.	Relative.	Absolute.	Relative.		Ant.-post.	Pelvic index.
Bontoc	14	34.9	22.0	26.4	16.6	75.6		
Highland	46	35.0	22.6	26.4	17.0	75.4		
Lowland	44	34.4	22.7	25.1	16.6	72.9	17.2	68.7
Total	104			25.6				
Women	10	32.0	21.8	26.0	17.7	81.2		
French men	40		18.9		16.9	80.8	(a)	
French women	30		16.3		18.4	91.8		
Belgian men	30					82.5		
Belgian women	30		22.0			94.5		
Negro men	2020		21.3		16.5			
European men	83				17.2			

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[a] Topinard (66).

The shoulders of the men are relatively (to the stature of course) wider than those of the women and the Lowland men have the widest shoulders. The hips of the women are relatively wider than those of the men. The $\frac{\text{hip}}{\text{shoulder}}$ breadth is naturally greater among the women, but this is much less for Igorots than for Europeans.

The Bontoc and Highland Igorots approach the European more closely than do the Lowland. The difference between the Bontoc and the Frenchmen is 5.2, the difference between the Lowland and the Frenchmen is 7.9, and the difference between the Igorot women and the French women is 10.6. The reason for this disparity on the part of the Igorot women is not so much in poorly developed hips as in well-developed shoulders due to field work and burden bearing.

The Igorots are intermediate between the European and the negro in relative hip breadth.

The pelvic index is given for the lowland group alone, because it was determined for no other.

THE UMBILICUS.

The position of the umbilicus in relation to the pubis and the suprasternal notch, although it is more variable than such fixed points as the two last mentioned, is of importance in type differentiation. Its importance embryologically can not be denied, but whether its position is due to developmental phenomena or not, remains to be determined. I present for the first time the index of the umbilicus, and emphasize its singificance.

The index is found by dividing the distance of the umbilicus from the pubic spine by its distance from the supra-sternal notch. This indicates its relative position on the body. If the index is high, the umbilicus is relatively near the suprasternal notch, but if low, it is relatively near the pubic spine.

I propose the name of omphalic index for the index of the umbilicus. Divisions into hyper-, meso-, and hypo-omphalic would follow naturally for the high, intermediate, and the low umbilicus. It is inexpedient at this time to attempt a definition of the limits of these three classes of omphalites, although I am inclined to believe that the Igorots are hypo-omphalic.

OMPHALIC INDEX.

Group.	Pubis.	Umbilicus.	Sternum.	Sternum to umbilicus.	Pubis to umbilicus.	Index of umbilicus.
Bontoc	81.9	95.6	129.6	34.0	13.7	40.3
Highland	77.9	91.9	126.5	34.6	14.0	40.4
Lowland	76.0	89.8	122.7	32.9	13.8	41.9
Total	77.6	91.5	125.3	33.8	13.9	41.1
Highland women	71.7	87.6	119.4	31.8	15.9	50.0

The sexual differentiation by the omphalic index is great. The women have an index that is 25 per cent higher than the men. The differences between the three groups of men is not so marked, but the lowland group resembles the women more than any other. The tall men have a low and the short men have a high index.

Childbearing in women may have some influence on the position of the umbilicus. So may the protrusion of the abdomen from any cause, such as obesity, ascites, rice feeding, etc.

The relation of omphalic index to age is as follows:

Omphalic index and age.

Group-age.	Number.	Pubis.	Umbilicus.	Sternum	Sternum to umbilicus.	Pubis to umbilicus.	Omphalic index.
Below 10	5	54.3	64.3	86.7	22.4	10.0	44.6
10–11	7	61.1	71.3	98.2	26.9	10.2	38.0
12–13	6	68.2	79.5	107.6	28.1	11.3	40.2
14–15	13	70.5	83.0	114.0	31.0	12.5	40.3
16–17	9	76.8	90.8	124.2	33.4	14.0	41.9

The index is high before the age of ten and decreases thereafter. The decided drop at 10–11 may be erroneous. At the age of 16 the position has reached that of the adult. The position of the umbilicus in the small male child is similar to that of the woman.

BODY LENGTH AND NECK LENGTH.

The stature may be divided into four parts: Head length (chin to vertex), neck length (chin to sternum), body length (sternum to pubic spine), and leg length (trochanter to sole). The leg length has been given, the other three remain. The body length is said to be 4 centimeters less than the distance from the suprasternal notch to the pubis(37), and the upper end of the leg is parallel with the lower end of the body, or 4 centimeters above the pubis. However, I find only 2 centimeters' difference between the pubis and the trochanter and as the pubic spine is more definite than the trochanter I prefer to use the spine.

The body length from the supra-sternal notch to the pubic spine is as follows:

Body length (truncus).

Group.	Absolute.	Relative.
Bontoc	47.7	30.0
Highland	48.6	31.3
Lowland	46.7	30.8
Total	47.7	31.0
Women	47.7	32.3

Compared with Martin's figures for the Malay Peninsula, the body length is slightly greater for the Igorots, and especially is this true of the highland group. The lowland is exactly the same as Senoi II, in absolute length, but relative to stature, the Lowland Igorot has a longer body. The body of the women is exactly as long as that of the men, and relative to stature it is longer.

The neck length presents unusual differences. The neck of the Highland Igorots is the shortest, even shorter than the women's, both absolutely and relatively; that of the Lowland Igorot is longer than any others, even the Bontoc being shorter.

Neck length (collum).

Group.	Absolute.	Relative.
Bontoc	7.2	4.5
Highland	6.4	4.2
Lowland	7.8	5.1
Total	7.1	4.6
Women	6.6	4.5

The women have relatively as long necks as any of the men; although they are not exactly swan-like, there is symmetry and beauty in their lines and proportions.

III. HEAD FORM.

The length of the head is measured from the glabella to the maximum occipital point (*torus occipitalis*), the greatest breadth is taken, and also the height from the external auditory meatus to the bregma. The following outlines are made with electric fuse wire:

1. *Sagittal:* From the glabella to the external occipital protuberance;
2. *Horizontal:* Above the superciliary ridges and around the maximum occipital point;
3. *Coronal:* From the root of the zygomatic process on each side across the vertex.

Electric fuse wire was chosen after trying many materials, because of its lightness, rigidity and pliability. If care is exercised, the shape of the head is retained perfectly, the hair interferring in only a few instances. This method of obtaining outlines of the head on the living, while open to objection, nevertheless furnishes a ready and convenient means of securing at least the approximate head form. The sagittal outline is especially valuable, because of its greater accuracy.

The measurements of the head are reduced to skull measurements by deducting 10 millimeters from each diameter, and the skull size as thus determined is used in the calculation of the cephalic index. The $\frac{\text{breadth}}{\text{length}}$ index is then classified as follows:

Hyper-dolichocephalic	70 and less.
Dolichocephalic	70 to 74.9
Mesocephalic	75 to 79.9
Brachycephalic	80 to 84.9
Hyper-brachycephalic	85 and more.

Aurel von Török's(68) classification is useful in determining the actual size of the skull and its length in connection with the $\frac{\text{breadth}}{\text{length}}$ index. He uses symbols which are the initial letters of the three groups representing the three sizes of length and the three of width of the skull, namely, small, medium, and large. These will be symbolized by their English equivalents, *s*, *m*, and *l* as follows:

	s=narrow (short).	m=medium.	l=wide (long).
	mm.	*mm.*	*mm.*
Greatest skull width varies 101 to 173 mm	101-125	126-149	150-173
Greatest skull lenght varies 143 to 224 mm	143-169	170-196	197-224

Each skull is given a number, 1 to 82, which corresponds to its length in millimeters; No. 1=143 millimeters and No. 82=224 millimeters.

Cephalic index—male adult Igorots.

Type.	m/s								m/m														l/l		Total.
Number	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54	56	58	
Dolichocephalic							1				1	5	7	3	8	6	5	2	3						41
Mesocephalic								1	3	2	6	6	9	3	6	3	2	1	1						43
Brachycephalic			1		1	1	2	2	1	3	4	1			2										18
1 hyperbrachycephalic at 30; 1 hyperdolichocephalic at 46																									2
Total																									104

Let the symbol above the line represent the head width and the symbol below represent the head length, then the classes fall almost entirely in the m/m group or medium-sized heads.

Class.	Number.	s/s	m/s	s/m	m/m	l/m	m/l	l/l
Hyperdolichocephalic	1	0	0	0	1	0	0	0
Dolichocephalic	41	1	0	0	40	0	0	0
Mesocephalic	43	0	1	0	42	0	0	0
Brachycephalic	18	0	7	0	11	0	0	0
Hyperbrachycephalic	1	0	0	0	1	0	0	0
Total	104	1	8	0	95	0	0	0

There are no heads larger than medium size, but there are 9 smaller ones, 7 of which are brachycephalic. The smallest head of the series is dolichocephalic. There is a preponderance of dolichocephalic heads [41] over brachycephalic [18] which indicates that the Igorots are largely a dolichocephalic people, with medium-sized heads and that the brachycephalic portion of the population has small heads.

A more detailed analysis reveals the relationship of the head form in different localities. It is to be seen that the Bontoc group is fundamentally dolichocephalic, the highland is largely dolichocephalic and mesocephalic, while the lowland is for the greater part mesocephalic and brachycephalic. The percentage of dolichocephalic heads decreases from 57 in the Bontoc group to 29 in the lowland; that of mesocephalic heads increases from 29 in the Bontoc to 46 in the lowland; while the percentage of brachycephalic heads increases from 14 in the Bontoc to 25 in the lowland group. It is of interest to note that 54 per cent of the brachycephalic heads in the lowland group belong to the m/s class, 46 belong to the m/m, and 86 per cent of the m/s brachycephals are in the lowland group, whereas only 14 per cent are found in the highland and none in the Bontoc. The Bontoc group has not only a larger percentage of dolichocephalic heads and a smaller of mesocephalic and brachycephalic than the other groups, but there are no small heads in the Bontoc group.

Cephalic index by locality.

Group.	Class.	Number.	s/s	m/s	m/m	Per cent.
Bontoc	Dolichocephalic	8	0	0	8	57
	Mesocephalic	4	0	0	4	29
	Brachycephalic	2	0	0	2	14
	Total	14	0	0	14	100
Highland	Hyperdolichocephalic	1	0	0	1	2
	Dolichocephalic	20	1	0	19	44
	Mesocephalic	19	0	0	19	41
	Brachycephalic	5	0	1	4	11
	Hypherbrachycephalic	1	0	0	1	2
	Total	46	1	1	44	100
Lowland	Dolichocephalic	13	0	0	13	29
	Mesocephalic	20	0	1	19	46
	Brachycephalic	11	0	6	5	25
	Total	44	0	7	37	100

It has already been demonstrated from von Török's classification of the cephalic index that neither the length nor the breadth of the Igorot head is above medium size, and at least one group, the Lowland, has head dimensions below medium size.

Head dimensions of the living.

Group.	Number.	Head.		$\frac{\text{Breadth.}}{\text{length}}$ index.[a]	Auricular bregmatic height.	$\frac{\text{Height}}{\text{length}}$ index.
		Length.	Breadth.			
Bontoc	14	18.8	14.5	77.1	13.1	70.0
Highland	46	18.9	14.7	77.8	13.3	70.4
Lowland	44	18.6	14.6	78.5	12.7	68.8
Total	104	18.8	14.6	77.6	12.9	68.6
Women	10	18.2	14.1	77.5	12.3	67.6
Bontoc (Jenks, 19)	32	19.2	15.2	79.1		

[a] The index should be reduced from 0.5 to 2 points to equal the skull index.

The Igorots are more dolichocephalic than the eastern Asiatic people, but less so than the tribes of India. The Bontoc and Highland $\frac{\text{breadth}}{\text{length}}$ index is dolichocephalic and slightly mesocephalic and the Lowland is mesocephalic. The women have the same $\frac{\text{breadth}}{\text{length}}$ index as the men and the $\frac{\text{height}}{\text{length}}$ index is similar to the $\frac{\text{breadth}}{\text{length}}$ in its relationships, but the women are less high headed than the men. The Bontoc and highland groups are higher headed than any other people of the Malay Peninsula or of eastern Asia, except the southern Perak Malays(1) who are four points higher.

As the Lowland Igorots, who are largely brachycephalic, have low heads and the Bontoc Igorots who are dolichocephalic have high heads, it is to be presumed that dolichocephalic, or long heads, are high, and brachycephalic, or short heads, are low. However, the reverse is known to be true, although when I first noticed the group variations, I thought the Igorots might be different in this respect from other people, but comparing the $\frac{\text{breadth}}{\text{length}}$ index of the head with the $\frac{\text{height}}{\text{length}}$ the result is as follows:

Comparison of $\frac{\text{breadth}}{\text{length}}$ with $\frac{\text{height}}{\text{length}}$ index of the head.

Index h/l	63	64	65	66	67	68	69	70	71	72	73	74	75
Dolichocephalic	1	3	8	7	4	4	5	2		1		1	
Mesocephalic	1	1	1	4	4	6	16	7	3	3	3		1
Brachycephalic				1	1	1	2	2	2	5	2		

The dolichocephalic heads are low, the brachycephalic are high and the mesocephalic are intermediate. How, then, can the low $\frac{\text{height}}{\text{length}}$ index of the lowland group be accounted for when it is known that this group is largely brachycephalic? A closer examination of the cephalic index reveals the fact that the dolichocephalic heads of the lowland group have a very low $\frac{\text{height}}{\text{length}}$ index which influences the average of the group so as to lower it. It is seen from the above table of comparative indices that the $\frac{\text{height}}{\text{length}}$ index of the dolichocephalic heads is grouped about 65 and 69. There are high long heads and low long heads, the latter are found largely in the lowlands, and the former are found largely in the highlands.

The widest head breadth compared with the narrowest forehead breadth gives a great difference between the Bontoc and lowland groups. The Bontoc, with the narrowest head, has the widest forehead, and the Lowland with a wider head, has the narrowest. The women have relatively wider foreheads than the men. The forehead of the Igorots is wider than that of the inhabitants of the Malay Peninsula, or of other Malays, as wide as the Northern Chinese, and a little less wide than the Aino(39).

Widest head breadth compared with narrowest forehead.

Group.	Widest part of head.	Narrowest part of forehead.	Difference.
Bontoc	14.5	10.5	40.0
Highland	14.7	10.3	44.0
Lowland	14.6	10.25	43.5
Total	14.6	10.3	43.0
Women	14.1	10.3	38.0

IV. PHYSIOGNOMY.

The morphologic face height is the distance from the chin to the nasion; and the physiognomic face height is from the chin to the hair line. The dimensions are practically the same for the Bontoc and highland groups, but the lowland group is smaller in every particular. The face width of the Bontoc and Highland is greater than that of the inhabitants of the Malay Peninsula, and is nearer that of the Chinese, Japanese, and Ainos. The physiognomy of the women is less in its dimensions than that of the men.

Dimensions of the face.

Group.	Number.	Physiognomic face height.	Morphologic face height.	Bizygomatic width.	Physiognomic index.	Morphologic index.
Bontoc	14	18.1	10.8	13.7	75.7	78.8
Highland	46	18.1	10.9	13.8	76.3	79.0
Lowland	44	17.5	10.7	13.8	76.0	80.4
Total	104	17.9	10.8	13.6	76.0	79.4
Women	10	16.6	10.3	13.1	79.0	78.6

The index of the physiognomy, which indicates the relative face width, is greatest for the mountain division and least for the Bontoc. It is greater for the Igorots than for the Japanese and Malays, but it is less than that of the Aino. The women's faces are relatively wider than the men's. The morphologic index which indicates the relative length of the face below the eyes is greatest for the Lowland and least for the Bontoc. It is less than that of any other Eastern Asiatic peoples, although the Mantra(40) are about the same.

The lower face height (chin to nasal septum) as compared with the artistic modulus and with the total head height (chin to vertex) is as follows:

Lower face height compared with the artistic modulus and total head height.

Group.	Number.	Total head height.	Artistic modulus.	Lower face height.	Relative lower face height to total head height.
Bontoc	14	21.8	7.3	6.7	31
Highland	46	22.0	7.0	6.6	30
Lowland	44	21.1	7.1	6.7	32
Total	104	21.6	7.1	6.7	31
Women	10	20.7	7.1	6.5	31

The Highland has the least lower face, the Lowland the greatest, and the Bontoc and the women are exactly intermediate. The Highland has the greatest total head height, the longest physiognomy, and the shortest lower face, therefore his frontal cranial height is the greatest of all the Igorots. This is true also of the auricular bregmatic height, and the head outlines show the same, therefore the several measurements corroborate each other. The artistic modulus of the Bontoc is nearer that of the Europeans than are the others.

NOSE.

The nasal dimensions considered with those of the mouth are given in the following table:

Nasal and oral measurements on the living.

Group.	Number.	Nose, length.	Nostril, breadth.	Nasal index.	Number.	Mouth, length.	Lip, width.	Mouth, length.[a]
Bontoc	14	4.1	4.0	97.6	6	4.4	1.1	Chinese 4.7
Highland	46	4.3	3.8	88.4	35	4.8	1.2	Parisian ♂, 5.0
Lowland	44	4.0	3.8	95.0	28	4.9	1.2	Parisian ♀, 4.7
Total	104	4.1	3.8	92.7	69	4.8	1.2	Negro 5.31
Women	10	3.8	3.8	100.0	10	4.4	1.1	Negress 5.1
Bontoc (Jenks 19)	82	5.3	4.2	79.2				

[a] Topinard (63).

The measurements of the mouth may be dismissed by stating that the lips of the Igorots are full, but not thick and protruding like those of the Negro, nor is the mouth so large. The Bontoc and the women have smaller mouths than the Highland and Lowland Igorots.

The height of the nose measured from the subnasal point to the nasion is 7 millimeters less than the average height of this feature of the inhabitants of the Malay Peninsula (41), and the breadth (*ala nasi*) is the same, whereas the height and breadth are but 2 millimeters less than that given by Annandale and Robinson (43) for the same people. The resulting nasal index is therefore 10 per cent greater than Martin's for the Malay Peninsula and about the same as that of Annandale and Robinson (1). The extremes of nasal index found are 72 and 115.[2]

The women of the Malay Peninsula have narrower noses than the men, while the Igorot women have wider:

It may be of interest to note that the nasal index of the dolichocephalic Lowland Igorots is 99.4, while that of the brachycephalic is 85. This would seem to indicate that there are two types of Igorots in the lowlands, the long headed being wide nosed, the broad headed not to such a degree.

EYES.

The eyes are measured by taking the distance between the inner corners (*commissura palpebrarum medialis*) and between the outer corners (*commissura palpebrarum lateralis*) at the junction of the lids.

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[2] Cunningham (11) gives the nasal index of 23 Australians (native males) which "are ranged in the immediate vicinity of 94" with extremes of 79 and 104. This at once suggests a relationship between the Australian aboriginal and the Igorot.

Eye measurements.

Group.	Number.	Inner.	Outer.	Eye width.	Eye width.[a]	
Bontoc	14	3.60	9.20	2.80	Parisians	2.75
Highland	46	3.30	9.20	3.10	Belgians	3.00
Lowland	44	3.35	9.05	2.85	Chinese	3.20
Total	104	3.40	9.10	2.85	Australians	3.34
Women	10	3.30	8.80	2.75	Negroes (Africa)	3.38

[a] Topinard(64).

The eyes of the Bontoc are the narrowest and they are also more widely separated than those of the others(70). Those of the highland group are the widest and they are also the closest together, while the lowland is between the other two in eye width and the inter-eye distance. The eyes of the women are narrower than those of the men, but the same distance apart as the group to which they belong.

The artistic conception of the European eye is that it should be equal in width to the distance between the two eyes, and the artists add that the mouth should be one and one-half times the eye in width of opening. The Igorots have a smaller mouth and greater distance between the eyes than the artistic ideal for the European(63).

FACIAL ANGLE.

The facial angle is determined directly with two brass bars bolted together at one end. One bar is placed in line with the external auditory meatus, the other with the glabella, and the apex of the triangle is opposite the point covering the junction of the nasal septum and the upper lip (subnasal point). This is not so accurate as the facial angle of the skull, and minor differences are not to be detected by this method, but it affords an approximate angle with ease and facility.

The facial angle of the Bontoc Igorots is not measured, but that of the Highland and Lowland Igorots is given with that of the women and of the boys.

Facial angle.

Group.	Number.	Facial angle.	Cephalic index.	Per cent.	Facial angle (per cent).				
					65° to 70°	71° to 75°	76° to 80°	81° to 85°	86° to 90°
Bontoc	0	0	Dolichocephalic	24	0	25	46	29	0
Highland	42	78°	Mesocephalic	48	2	40	33	21	4
Lowland	17	77°	Brachycephalic	10	10	30	50	10	0
Total	59	77°.5							
Women	10	80°							
Boys 5	2	86°							
Boys 6-10	3	78°							
Boys 11-12	5	76°							
Boys 13-14	5	79°							
Boys 15-16	6	78°							

The Highland and Lowland Igorots have practically the same angle, while that of the women is greater. The angle decreases with age, for example: Four boys below the age of 10 have an angle above 80°, after this age it is below 80°.

When compared with the cephalic index prognathism becomes evident among the brachycephalic, while the dolichocephalic are less prognathous and the mesocephalic are clearly mixed. The brachycephalic resemble the Negrito in their prognathism.

MALAY AGAINST IGOROT.

Four indices which are considered to be important in type differentiation may be compared with the same figures of the inhabitants of the Malay Peninsula(44). The cephalic index $\left(\frac{\text{breadth}}{\text{length}}\right)$ will be taken first, because it is the most important.

Comparison of cephalic indices of Igorot and Malay.

Group.	Index.	Group.	Index.
Bontoc	77.1	Blandas	77.1
Highland	77.8	Semang	77.9
Lowland	78.5	Reine Senoi	78.5
		Besisi	82.4

The exactness with which the Bontoc and Blandas, the Highland and Semang, and the Lowland and "Reine Senoi" correspond is remarkable. The similarity between the Igorots and the inhabitants of the Malay Peninsula is so exact that if cephalic index is the criterion of type, the conclusion must be that they are identical types of people.

The height index of the head is given next, because it is closely associated with the cephalic index.

Comparison of height indices of Igorot and Malay.

Group.	Index.	Group.	Index.
Bontoc	70.0	Blandas	64.6
Highland	70.4	Semang	65.5
Lowland	68.3	Reine Senoi	67.0
		Besisi	68.0

The correlation of head height is almost reverse in its relation to the horizontal diameters (cephalic index). Could the low headed dolichocephals be eliminated from the lowland group, the index would be raised higher than the highland, and the groups of Igorots would then correspond with those of the Malay Peninsula, excepting that the Igorot head is higher.

The morphologic face index is correlated below:

Comparison of the morphologic face indices of Igorot and Malay.

Group.	Index.	Group.	Index.
Bontoc	78.8	Blandas	84.6
Highland	79.0	Semang	82.5
Lowland	80.4	Reine Senoi	82.5
		Besisi	81.8

Martin's groups have longer faces below the eyes than the Igorots. The lowland is more like the Reine Senoi than are the Bontoc and highland groups, which diverge from the other Malays. This may be explained on the assumption that the Bontoc and highland groups have greater European intermixture.

Finally the nasal index is correlated as follows:

Comparison of the nasal indices of Igorot and Malay.

Group.	Index.	Group.	Index.
Bontoc	97.6	Blandas	76.6
Highland	88.4	Semang	83.5
Lowland	95.0	Reine Senoi	86
		Besisi	78.9

The disparity between the groups is marked. Again, if the type of dolichocephalic Igorots with very wide noses be eliminated, the disparity is diminished.

The Malays of the inland part of the peninsula according to Martin are mesocephalic with one group brachycephalic; hypsi to orthocephalic; brachyfacial to mesofacial; and mesorhinian to platyrhinian. The Igorots are mesocephalic and dolichocephalic; hypsicephalic; brachyfacial; and platyrhine. They are also slightly prognathous.

V. DESCRIPTIVE CHARACTERS.

The skin of the Igorot is characteristically light brown, but the tint varies with individuals and it is different in different families(72, 73). The influence of light and shade may be noticed; those who work in the sun are darker than those who serve in the house and the women and the children are lighter than the men. The whole family of one chief, including several young men and women who stay indoors a great deal is so light brown in color as to be classed as yellow. In a few individuals a tinge of red may be seen, or the face appears bronzed, some Igorots strikingly resembling the North American Indian. The coloring shows a trend towards lightness rather than the reverse, and this is manifested most strongly among the Bontocs.

Skin color (per cent).

Group.	Number.	Golden-brown.	Light brown.	Brown.	Dark brown.
Bontoc	12	--------	30	60	5
Highland	45	5	11	71	13
Lowland	35	2	8	83	8
Total	92	3	18	74	11

The relative number of brown individuals increases in the Highland and reaches its limit in the Lowland. The lightest colored individuals are found in the highlands. The one golden-brown individual of the lowlands is a young man who for several years has been a servant in an American family, where he worked principally indoors and wore the regular European clothes of the Tropics.

The hair is invariably black, straight, and coarse. A few individuals with wavy hair were observed, but not one of those measured had a noticeable wave in the hair. This is remarkable when one considers how closely the Igorot resembles the Negrito in other characters. I can account for the predominance of the straight hair in one way only—it is dominant to the kinky hair of the Negrito, and in the course of centuries the kink has disappeared leaving only an occasional trace, such as the few wavy-haired individuals I observed casually, and those noticed by Jenks(20) among the Bontoc Igorots(71). The wavy-haired individuals probably belong to the Senoi type of Martin.

The brows of the Igorots are never so beetling, and the brow ridges never so prominent as among the Filipinos of the coasts and other parts of the Islands. However, there is a slight difference of the size of the superciliary ridges among the Igorots which may be presented in three groups, small, medium, and large.

Brow ridges (per cent).

Group.	Number.	Small.	Medium.	Large.
Bontoc	10	20	70	10
Highland	45	11	42	47
Lowland	42	16	65	19
Women	10	70	30	-------

The brows of the highland group stand out clearly, because they are larger than those of the other two groups, and the brows of the women are small, as is to be expected.

The Igorot nose may be divided into three classes by the profile view—aquiline, straight, and australoid. With the side may be coupled the front view, in which two factors claim attention, the direction of the nostril openings, and the amount of flare to the alæ of the nostrils. Each of these characters has three qualities which may be combined with the three of the profile to make up three composite types. The aquiline nose has narrow nostrils that open downward and the nasal index is low. The straight nose has wider nostrils that open downward and forward, and the nose is compact without extremely flaring nostrils. The australoid nose has wide flaring nostrils that open almost forward and the nasal index is high, the nose extremely platyrhine.

Types of nose (per cent).

Group.	Number.	Aquiline.	Straight.	Australoid.
Bontoc	5	0	80	20
Highland	46	16	28	56
Lowland	32	6	22	72
Total	83	12	30	58
Women	10	10	70	20

Of these three types, the aquiline is found most frequently among the Highland Igorots, the straight among the Bontoc, and the australoid among the Lowland. The nose of the women is usually straight or australoid. [Plates II, III, and IV.]

HEAD OUTLINES.

The head outlines are treated as composites in groups, according to cephalic index and by locality. Only the sagittal outlines are utilized because they are more accurate than the other, and illustrate more distinctive differences.

The composites are made by drawing each outline on transparent paper with the mid-point of the line which connects the glabella and the occipital tubercle, as well as the line itself, superimposed upon the same point and line for each drawing. After all the outlines of one group are drawn in this way the heaviest line is reproduced as the composite on another sheet of paper.

The composites grouped according to cephalic index indicate what is to be expected from von Török's classification, namely, the dolichocephalic heads are the largest and the brachycephalic the smallest, while the mesocephalic are intermediate in size. (Fig. 3.) The composite

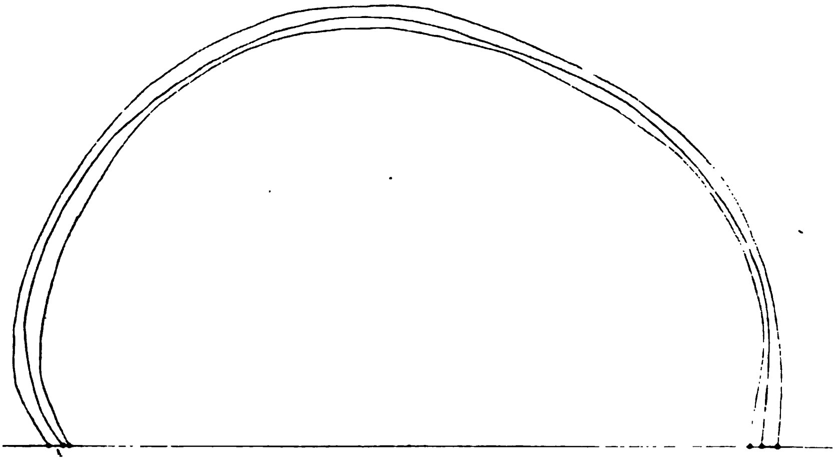

FIG. 3.—Composite sagittal outlines of 104 Igorots: 41 dolichocephalic, largest outline; 43 mesocephalic, intermediate outline; 18 brachycephalic, smallest outline.

curves of the three groups are similar. The forehead of the brachycephalic protrudes slightly and the occipito-parietal region is somewhat flattened.

When the composite dolichocephalic head outline of the Igorots is compared with a similar outline from an equal number of negroes I measured in Baltimore at the Johns Hopkins Hospital Dispensary in 1906, the data being as yet unpublished, and an equal number of white students of the University of Michigan I measured at Ann Arbor in 1905 to 1907(4), some striking differences may be seen. (Fig. 4.) The head of the Igorot is the tallest and shortest of the three,

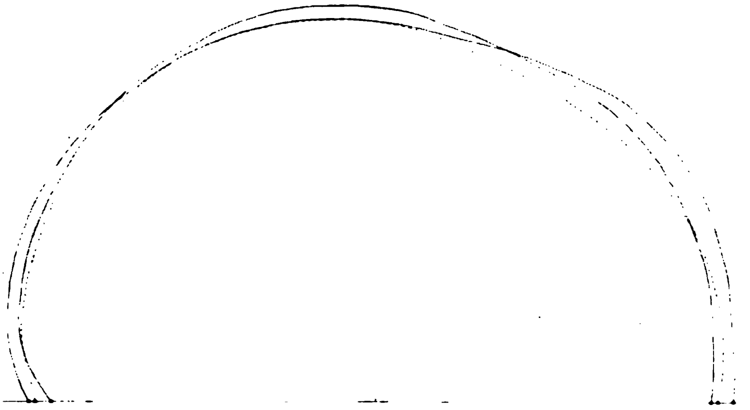

FIG. 4.—Composite sagittal outlines of the dolichocephalic heads of Igorots, negroes, and white students: Igorot, the short, high outline; white, the long, low outline; negro, the broken outline.

whereas that of the white student is the lowest and longest. The forehead of the negro is low and receding, while that of the Igorot and white student are high and prominent. The head region immediately above the somasthetic area of the brain is prominent in the Igorot and in the negro, but not in the white student. The white student has a relatively large frontal region, the negro has a relatively large body sense and motor region, while the Igorot has both. The Igorot represents a protomorph, or a mixture, while the negro and the white student represent specialized products of evolution, or definite types. The Igorot contains elements similar to each of the others, at least this is true of the dolichocephalic.

The brachycephalic head outlines reveal somewhat different characteristics. (Fig. 5.) The white student is again the longest, but it is also the tallest, the Igorot has a rounded outline with full, high forehead and the negro has a bombé forehead high in the frontal region. There are only 6 brachycephalic negro head outlines and the composite for that reason is not a representative one.

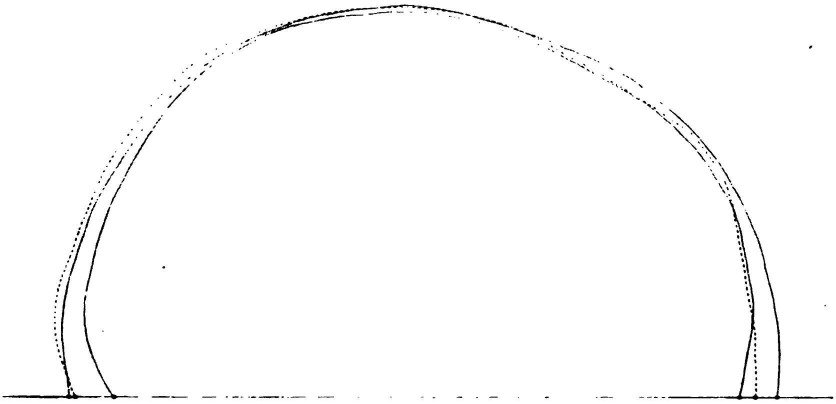

FIG. 5.—Composite sagittal outlines of the brachycephalic Igorots, brachycephalic negroes, and brachycephalic white students: Igorot, the inner solid outline; white, the outer solid outline; negro, the broken line.

The mesocephalic head outlines represent more definitely than the dolichocephalic the important differences denoted by the latter. (Fig. 6.) The Igorot

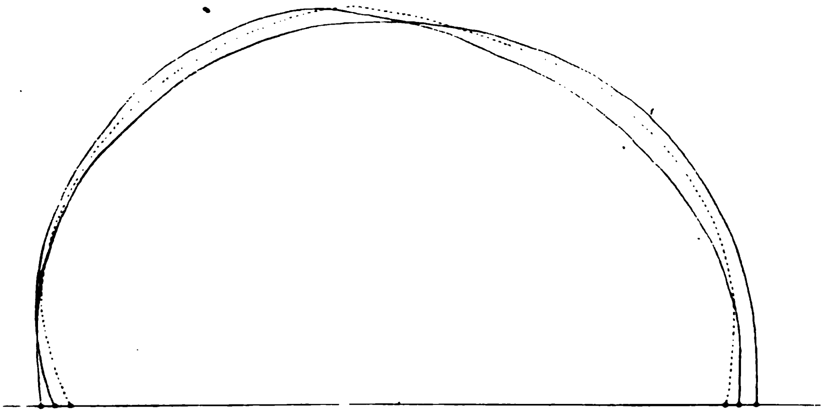

FIG. 6.—Composite sagittal outlines of the mesocephalic Igorots, mesocephalic negroes, and mesocephalic white students: Igorot, the broken outline; white, the long, solid outline; negro, the short, solid outline.

head outline is an exact blend of the white student and the negro, except that it is shorter and slightly higher. The white student's head is relatively large frontally, the negro's is relatively large parietally, and the Igorot's is relatively well developed throughout.

The sagittal outlines of the 10 Igorot women of Atoc when compared with similar outlines of 10 women students at the University of Michigan selected with the same cephalic index show great dissimilarity. (Fig. 7.) The white student head is longer, the Igorot head is shorter and higher, and both are depressed beneath the occipital and frontal regions. The somesthetic region of the Igorot is protuberant, while that of the white student is unobtrusive. The small number of individuals and the difficulty with the long hair of the women vitiate the records somewhat, but the differences in height and length are of the same nature as in the men, although intensified in the women.

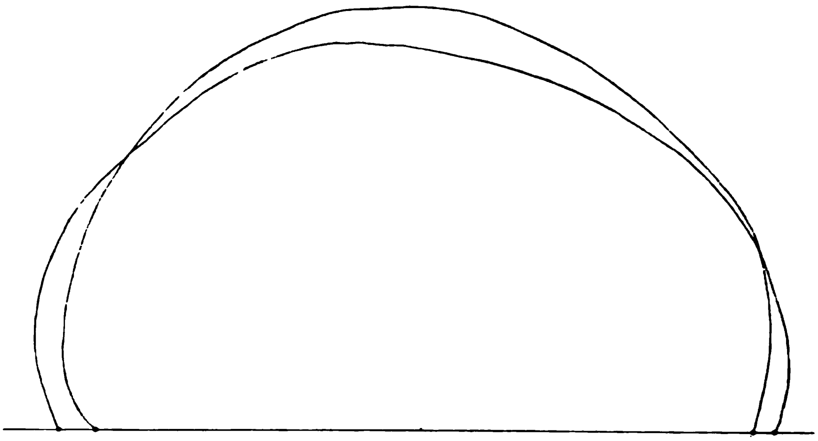

FIG. 7.—**Composite sagittal outlines of the heads of 10 Igorot women and 10 American college women: Igorot, short, high outline; American, long, low outline.**

The distinguishing differences between the Igorot and the American student are the length and height of the head. The Igorot's is short and high, the American student's is long and low. The Igorots, male and female, carry heavy burdens by straps across the top of the head, which may influence the height of the head from compensatory hypertrophy following the continual stimulus of great pressure. The generous muscular development of the Igorot may also have some influence in heightening the head, by increasing the size of the somesthetic area of the brain.

The head height is a racial trait, as well, which may be inferred by comparing the sagittal outlines of the three groups of Igorots. (Fig 8.) The Highland Igorots have longer, higher heads than the Lowland Igorots. The Bontoc head is longer than the others, but not so high as the Highland. This is an additional differentiating fact between the three groups, and again the Bontoc is more nearly like the white, whereas the Lowland is less so than the others.

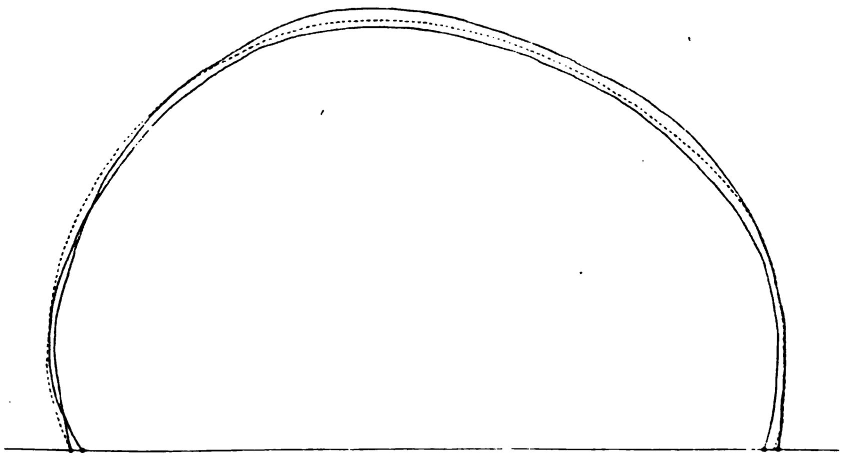

FIG. 8.—Composite sagittal outlines of the three groups of Igorots: Bontoc, the broken outline; Highland, the large solid outline; Lowland, the small solid outline.

EARS.

The ear of the Igorot is a most typical feature and a true racial character. Not all the ears are alike, indeed there are at least three well-defined forms, and many variations of the three. The typical Igorot ear is found oftener than any other kind, and its frequent presence merits a special description and portrayal by photograph. (Plate V.)

The typical Igorot ear is large and long and somewhat rectanguar in shape. The superior border of the helix is smooth, thin, gracefully rounded, and the posterior border is straight. The anthelix circumscribes the concha in the shape of a large oval with its apex at the *incisura intertragica*. The lobule is square and flat, the inferior border usually joining the cheek at right angles. The ear does not stand out from the head, neither is it pressed close to it, but occupies an intermediate place, and is beautiful and graceful in both form and position. (Plate VI.)

There is not a line or character about the Igorot ear to relate it with the anthropoid apes nor with any of the primitive people of the world, so far as I am able to judge. It is not like the Negrito ear, which is short and round, the helix of which passes horizontally backward from the superior end of the base, the anthelix forming a roll that often gives the ear the appearance of having a double helix, and the lobule is round or pointed. (Plates VII and VIII.) It has none of the characteristics of the Australian aboriginal ear(11) which is similar in many ways to the anthropoid. Darwin's tubercle is present more frequently in the men than in the women, which is true of Europeans(52). I have seen ears resembling the Igorots on Spaniards, Englishmen, and

Americans, but I shall discuss that subject fully in a forthcoming article on Filipino ears. The ear is a European one, and characteristic of one of the finer types of Europeans.

The other types of ears among the Igorots resemble the Negrito, and the Malay or Chinese ear without lobule. Three types of ears may be distinguished, which are distributed as follows:

Types of ears.

Group.	Number.	Typical.	Oval, no lobule.	Round.
Bontoc	12	9	2	1
Highland	45	29	12	4
Lowland	34	20	6	8
Total	91	58	20	13
Women	10	9	1	0
Boys	27	20	3	4

The Bontoc Igorots have a relatively larger number of typical ears than the other groups, although the Highland Igorots have almost as great a relative number, but the Lowland have the least, and also a greater number of round ears (Negrito?).

The ear index of Topinard (65) is useful in differentiating the types, but Schwalbe's morphological index was not utilized. The ear index is the $\frac{\text{greatest breadth x 100}}{\text{greatest length}}$

Ear measurements.

Group.	Number.	Breadth.	Length	Ear index.
Bontoc	12	33.1	57.2	57.8
Highland	46	31.9	59.3	53.8
Lowland	44	31.4	56.7	55.3
Total	104	31.8	57.9	55.0
Women	10	28.8	49.7	57.9

Ear index (Topinard).		
Type.	Number.	Index.
Europeans	8	54.0
Melanesians	8	59.5
Polynesians	8	60.0
Negroes (African)	18	61.2

The Highland Igorots have the longest ears and the lowest index, with the Bontoc second and the Lowland third in ear length, but the Lowland index is less than the Bontoc. The ear index is not an absolutely reliable indication of ear type, but with the aid of descriptions it is serviceable. The index of the typical Igorot ear is low because the ear is long and not round. The ear should be one of the best marks to determine the nature of heredity, because it is not subject to sexual selection in the way that other features such as the eyes or nose may be.

and there is no reason to believe that natural selection would affect it. For the same reasons this feature should be one of the best marks to determine racial purity.

The ear marks of a people may be significant.

CORRELATIONS.

The correlation of cephalic index and stature is determined by averages and percentages. The average stature of the dolichocephalic Igorots is 157.1 centimeters, that of the mesocephalic is 155.2, whereas the stature of the brachycephalic is only 152.2 centimeters.

Correlation of cephalic index and stature (per cent).

Index.	Stature below 150 centimeters.	Stature 150 to 160 centimeters.	Stature above 160 centimeters.
Dolichocephalic	16.6	64.3	19.1
Mesocephalic	20.0	62.5	17.5
Brachycephalic	31.8	54.5	13.7

There is a greater proportion of comparatively tall individuals among the dolichocephalic Igorots, and a greater of small individuals among the brachycephalic than among the mesocephalic, but the difference between the mesocephalic and brachycephalic is greater than that between the mesocephalic and dolichocephalic. A larger per cent of each index is found between 150 and 160 centimeters, which is to be expected in a much mixed, endogamous people. However, it is in the extremes that aboriginal types are to be searched for, and it is the extremes where the differences are greatest.

The correlation of cephalic index and relative arm length is not so great as the correlation of cephalic index and height, but it is in the same direction. The long head and the tall height are parallel and so are the long head and the relatively long arm. However, the correlation is slight.

Correlation of cephalic index and relative arm length (per cent).

Groups.	Below 43.0 centimeters.	Between 43.0 and 45.5 centimeters.	Above 45.5 centimeters.
Dolichocephalic	14.2	64.4	21.4
Brachycephalic	26.3	52.3	21.0
Mesocephalic	31.0	54.8	14.2

The average relative arm length is 44.3 for the dolichocephalic, 44.2 for the brachycephalic, and 43.9 for the mesocephalic. In groups above 45.5 there are 21.4 per cent dolichocephalic, 21 per cent brachycephalic, and 14.2 per cent mesocephalic. In groups below 43.0 there are 14.2 dolichocephalic, 26.3 brachycephalic, and 31 mesocephalic.

The dolichocephalic have relatively longer arms than the mesocephalic, while the brachycephalic have an intermediate relative arm length.

Correlation of stature and relative arm length (per cent).

Stature.	Below 43.0 centimeters.	43.0 to 45.5 centimeters.	Above 45.5 centimeters.
Above 160 centimeters	9	82	9
150 to 160 centimeters	23.3	53.4	23.3
Below 150 centimeters	38	47.6	14.4

There is a progressive increase of relatively short arms (below 43) from absolute tallness to absolute smallness, and a progressive increase of arms of relatively intermediate length (43 to 45.5) in the opposite direction, while the number of long arms (above 45.5) increases from tallness, through smallness, to medium size in stature. Continuing the analysis of cephalic index combined with stature and relative arm length a table is presented as follows:

Analysis of cephalic index combined with stature and relative arm length (per cent).

Stature and group.	Below 43.0 centimeters.	43.0 to 45.5 centimeters.	Above 45.5 centimeters.
Above 160 centimeters:			
Dolichocephalic	0	100.0	0.0
Mesocephalic	12.5	62.5	25.0
Brachycephalic	20.0	80.0	0.0
150 to 160 centimeters:			
Dolichocephalic	14.8	55.6	29.6
Mesocephalic	30.4	56.6	13.0
Brachycephalic	30.0	40.0	30.0
Below 150 centimeters:			
Dolichocephalic	33.3	50.0	16.6
Mesocephalic	50.0	40.0	10.0
Brachycephalic	20.0	60.0	20.0

The Igorots may be divided into four groups by the above correlations:

1. Tall dolichocephalic Igorots with long arms.
2. Small dolichocephalic Igorots with short arms.
3. Mixed mesocephalic Igorots.
4. Brachycephalic Igorots with intermediate arm length.

The correlations and differences suggest that three steps of racial mixture preceded present conditions. First, a small, dolichocephalic people with relatively short arms and a brachycephalic people mingled and partly fused. They were then joined by a tall, dolichocephalic, long-armed people already partly fused with the brachycephalic, and subsequent fusion was again altered by contact with the brachycephalic people. The last contact was quite recent and the brachycephalic people are more distinct as a type than either the tall dolichocephalic or the small dolichocephalic, and they are also present in greater number.

VI. SOMATOLOGIC RACE TYPES.

Stratz(56) divides mankind into three groups, *protomorphs* or nature folk, *archimorphs* or highly differentiated peoples, and *metamorphs* or mixed races. These may be used in connection with the canon of Fritsch and the artistic modulus(24) as comparative standards.

The canon of Fritsch takes as its standard the length of the vertebral column and the other body measurements are compared with this(57). The length of the vertebral column is equal to the distance from the *symphysis pubis* to the nasal spine. With this basis, photometry may be made an adjunct of anthropometry when interpreting the length relations of the body parts. The artistic modulus is the total head height from chin to vertex, and it is used in relation to stature. The modulus of Geyer, which is the stature equal to 8 total head heights, is the artistic ideal for the European.

With this explanation the following classification is given.

The protomorphs comprise the Australian, Papuan, Hottentot, American Indian, Eskimo, Philippine Negrito, and the Pigmy of Africa.

The archimorphs are the leukoderm or white, the melanoderm or black and the xanthoderm or yellow men.

The metamorphs are mixtures of the other groups, and are found along the zones between the black, white, and yellow races; in northern Africa, eastern and southern Asia and in the islands of the Pacific.

The protomorphs are short in stature with relatively long total head height, which is in the lower face and not in the cranium, and their arms are relatively long. They conform to the canon of Fritsch except in the relative length of arm, and to the artistic canon except in the relatively large head.

The melanoderms are relatively short in stature, long in arm, and short in upper head height, nasal spine to vertex.

The xanthoderms are relative short in stature, in length of leg and in upper head height. A slight departure from this may be noted in the females of each group. A table of individual records among which are three Igorot men, is shown for comparison. (Table VIII.)

A more intricate and detailed comparison, as in the accompanying charts, reveals some noteworthy differences between the three Igorots shown by fig. 9. The first [No. 60] is tall and dolichocephalic; the second [No. 3] is intermediate in height and mesocephalic; while the third [No. 83] is small and brachycephalic. Other distinguishing characters are to be noted, such as the almost uniform conformity of No. 60 to the canon of Fritsch and the modulus of Geyer, although the body is slightly longer and the legs slightly shorter than the European,

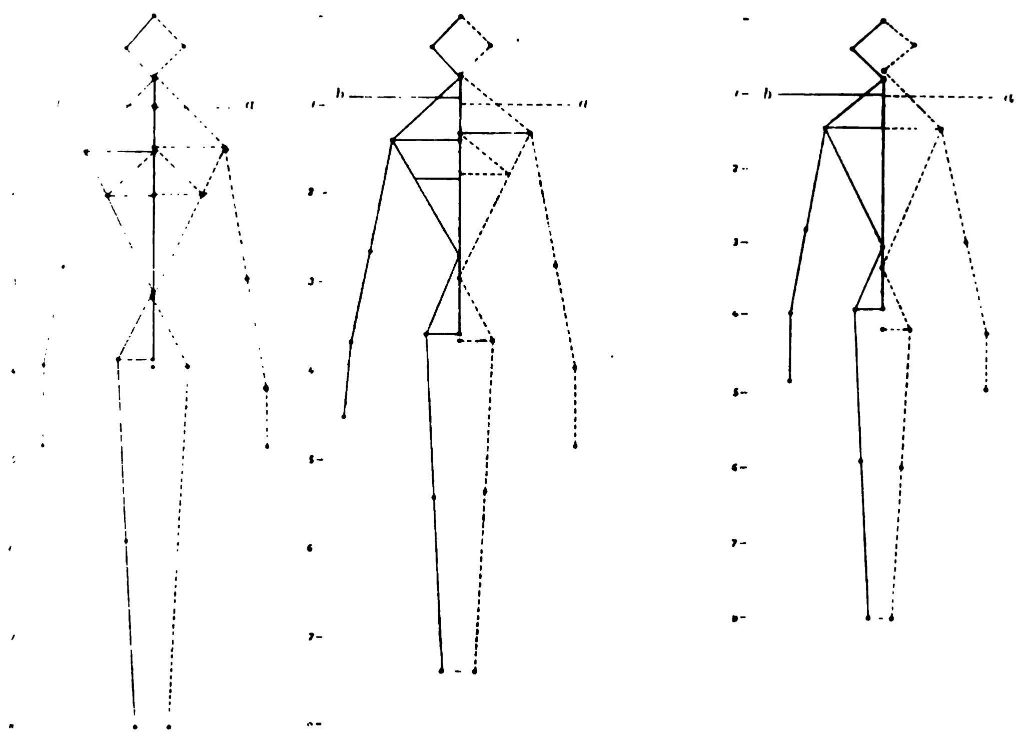

FIG. 9. The solid lines are Europeans, the broken lines Igorots. The figure on the left represents an Igorot man (No. 60), stature 168 centimeters, from the highlands. The middle figure represents an Igorot man (No. 3), stature 155 centimeters, from Bontoc. The figure on the right represents an Igorot man (No. 83), stature 142 centimeters, from the lowlands. The left half of each figure (solid lines) is the European standard male canon of Fritsch, modified to the Igorot stature, and the right half of the figure (broken lines) is the Igorot canon of Fritsch. The horizontal lines numbered 1 to 8 indicate the number of total head heights in the Igorot's stature according to the artistic modulus of Geyer. The lines *a* and *b* point to the chin.

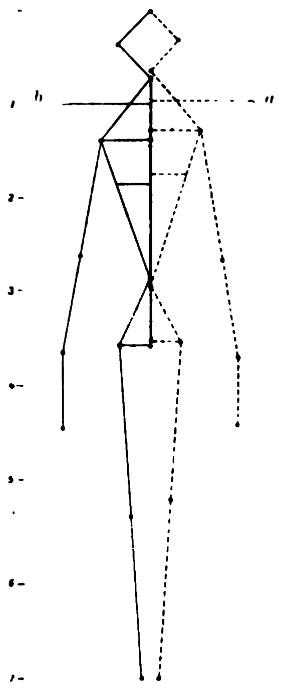

FIG. 10.—The left side of the figure (solid lines) is Merkel's standard female European according to the canon of Fritsch, and on the right side (dotted lines) is a typical Igorot (No. 52) according to the same canon. *a* and *b* point to the chin.

and the upper arm is longer and the hand shorter. No. 3 presents relations of body parts similar to the protomorphs. The body length is only 7.4 times the total head height, and the greater part of the latter is in the lower face. The arm is considerably longer than that of the European, the body is also longer, while the umbilicus is notably lower in this type. The chief characteristics of No. 83 are long body, short legs and short upper head height. The characters which the three Igorots have in common and in which they are different from the canon of Fritsch are long bodies, short legs, long arms, short necks, long lower head height, and short upper head height. The tall Igorot is most like a white man in all these characters and the small Igorot is least like him.

When a typical Igorot (No. 52) is compared with Merkel's normal woman's figure(57) it is noticed that there is no great disparity between the two. (Fig. 10.) The neck and the upper head of the woman are longer than those of the Igorot, while the body and legs of the Igorot are slightly longer than those of the woman. The abdomen (waist) of the woman is longer, the umbilicus higher than in the Igorot.

There may be then, three or more types of Igorots, representing three or more fundamentally different groups of mankind, and these three have fused in part and remained separate in part. An average individual Igorot resembles in form the woman of Europe, and represents a protomorph of the nature folk.

Consider the average Igorot stature, leg length, and arm length in relation to the classification of Stratz, and some incongruity is apparent. The average relative arm length of the xanthoderm and of the Igorot is 44.0, while that of the protomorph is 47.2. The average relative length of the leg is 51.6 for the Igorot, 52.0 for the protomorph, and 46.4 for the xanthoderm. The Igorot arm is short, like that of the xanthoderm, and the Igorot leg is long, like that of the protomorph. This indicates that the Igorot has elements of both the protomorph and the xanthoderm if we accept Stratz's classification, or if not, it at least indicates a relationship between the Igorot, the protomorph, and the xanthoderm. Similar elementary characters enter into the composition of each people. Stratz's classification may be misleading in that his types are too simple, yet do not represent fundamental units of structure, but they may be useful in showing general relationships that exist at present. The xanthoderm, represented by the Chinese and Japanese, is more nearly like the group of Igorots that resemble the European, and the resemblance of Igorot to xanthoderm may be due to a European mixture in each. On the other hand the reason for the resemblance of the Igorots and the protomorph may be that each has the same fundamental type represented in its make up. The Igorots that resemble the protomorph are those which are most like the Negrito. Here may lie the secret of the whole matter. The Negrito or pigmy forms the substratum of the East, on which are engrafted in devious ways and varying proportions some of the early types of Europe, and the many different peoples of the East are the results of this varying mixture. This seems too simple to be plausible, but the deeper the study the greater the revelations of its truth. The type of Igorot that resembles the Negrito is not a protomorph but has protomorphic characters. Another type of Igorot that is similar to Martin's Senoi also has protomorphic characters, but they are unlike those of the Negrito. The individual Igorot that resembles a true protomorph (No. 3) is an intermediate type, unlike either the Senoi or the Negrito. The protomorph is not a true type, but a composite or blend of other more distinct types. The Senoi itself is not a pure type, but is mixed, as may be readily demonstrated.

Judged by the canon of Fritsch and the artistic modulus of Geyer according to the classification of Stratz, the Igorot has characters of the protomorph, the xanthoderm, and the leukoderm; does not resemble the melanoderm, but is in reality a metamorph. The protomorph characters are due to the Negrito, the xanthoderm to a type found among Chinese and Japanese, but of European origin, the leukoderm characters to another European type.

VII. THREE SELECTED TYPES.

When the 104 adult male Igorots are separated into the three groups, dolichocephalic, mesocephalic, and brachycephalic, and these groups are subdivided according to the shape of the head outlines, three types, 2 dolichocephalic and 1 brachycephalic, are separated with ease. (Figs. 11 and 12.) The remainder could be subdivided with difficulty, and they

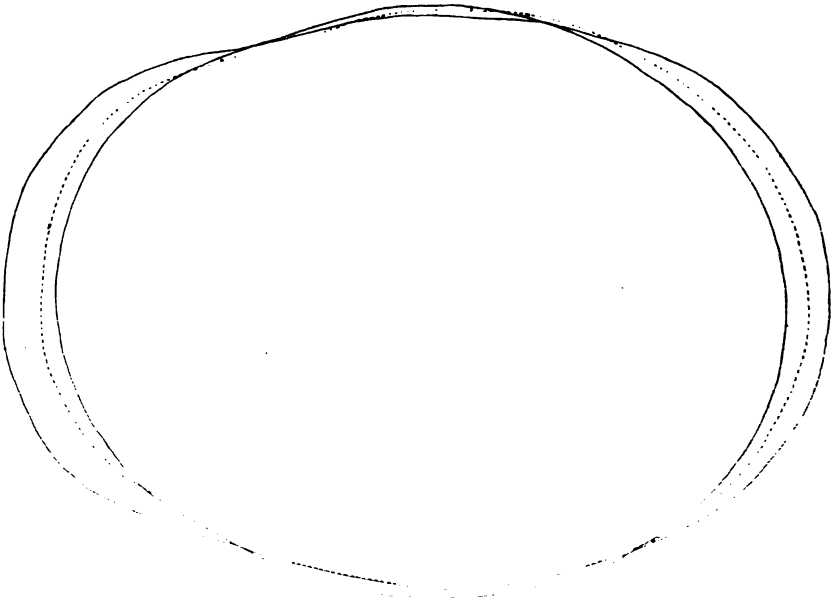

FIG. 11.—Horizontal outlines of three Igorot heads to represent the three selected types M, A, and N: M, the long outside outline (solid); A, the broken outline; N, the short inside solid outline.

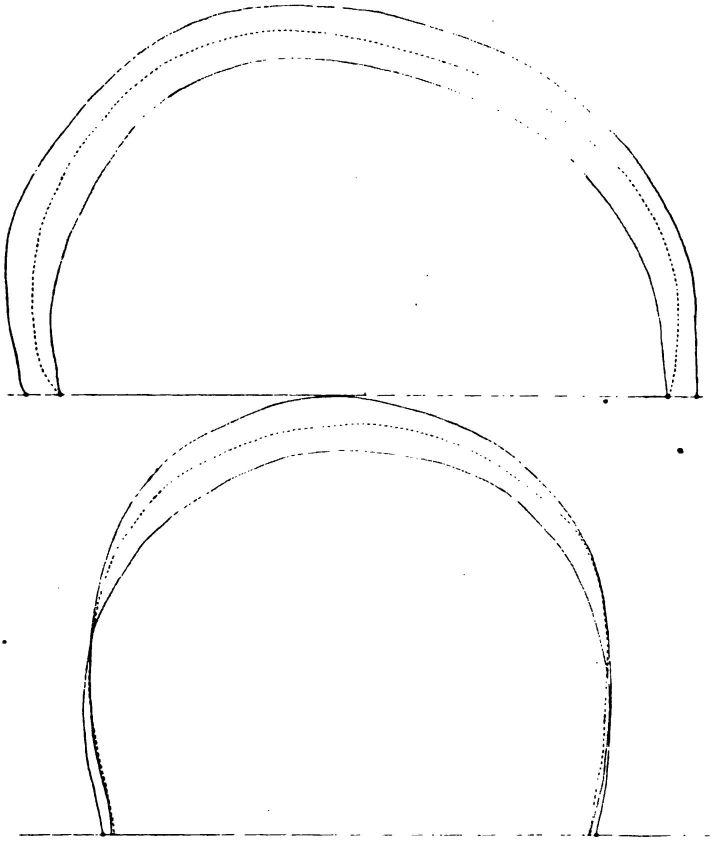

FIG. 12.—Sagittal and coronal outlines of three Igorot heads to represent the three selected types: M, the outside solid outline; A, the broken outline; N, the inner solid outline.

are not so treated because the individuals resemble one or the other of the three types, into which they shade insensibly.

The dolichocephalic type M has a long, narrow, high, square head. The dolichocephalic type A has a long, low, oval head with flat top that slopes gently forward. The occiput and forehead bulge slightly. The head of the brachycephalic type N is low and round, and the forehead is receding. Other descriptive characters are as follows:

Character.	Type M.	Type A.	Type N.
Hair	Straight coarse black	Straight coarse black	Straight coarse black.
Skin	Golden-brown	Brown	Brown.
Brows	Heavy	Medium heavy	Medium slight.
Nose	Straight slightly aquiline	Large semi-australoid	Short semi-australoid.
Ears	Typical Igorot	Oval no lobule	Oval or round.
Facial angle.	78.7	77.7	75.7.
Occupation	Petty chiefs and councilors	Laborers, 1 policeman	Day laborers.
Residence	Bontoc and Highland largely	All 3 regions	Lowlands largely.

The letters M, A, N, are selected for obvious reasons. I believe the three represent a type of the Malay, the Aboriginal of the East, and the Negrito.

In addition to the descriptive characters, the measured ones are given in averages and indices, or relative factors. (Table IX.) The characters in which the three types resemble each other are nasal index, hair, relative shoulder width, eye width, relative leg length and relative hand length, and it may be said that these characters are more representative of the Igorots than any other, unless it be eye color which is so uniformly brown in all Igorots, that no records are made. The differentiating characters are chiefly stature, skin color, ears, head length, brachial index, cephalic index, total head height, relative lower face height, the distance between the eyes, and the position of the umbilicus. The types may be summarized as follows:

Type M.—The individuals of this type are petty chiefs, councilors, etc., who reside chiefly in Bontoc and the highlands of Benguet. They may be differentiated from other Igorots by their tallness and occasional light, golden-brown skin, heavy brows, slightly aquiline nose, and large ears that have a square lobule, the lower border of which terminates abruptly against the corners of the mandible. Other distinguishing characters are the head length and height and the forehead width, which are greater than found in any other group of Igorots. The relatively long leg, small brachial index, and high umbilicus are characteristics to be emphasized. The cephalic index, nasal index, and ear index are the smallest found. Otherwise stated, the head, nose, and ears are longer and narrower than any others. The eyes are also farther apart, and the upper head is relatively higher than the lower face, which is broad, but not long.

Type A.—The members of this type are laborers (farmers, police, etc.) from all parts of Benguet and from Bontoc. Their differential descriptive characters are the unusually small stature, brown or dark brown skin, large, wide, flat australoid nose, rounded or oval ear without lobule, and the relatively broad shoulders. Their low, long, oval, flat-topped head with bombé forehead and narrow-eyes are distinctive. The arm and forearm are relatively short, and the brachial index is low.

Type N.—This type may be recognized readily by its small stature, brown skin, delicate brow ridges, small, round head with excessively developed parietal and temporal regions, narrow, retreating forehead, short nose, small round ears, and projecting jaws. The individuals of this type have relatively long arms and forearms, short hands, and a high brachial index. The cephalic index is high, the nasal index low and the ear index high. Especially to be noted are the low umbilicus close to the pubis, the relatively high total head height due to the large lower face, and the narrow space between the eyes.

There can be no doubt but that these three types are present among the Igorots, but what they represent is not so easy to decide. Type M resembles the European and it may be considered to be of European origin, recent or remote. Type N is in many respects like the Negrito, and is positively identified with the protomorphs of Stratz. Type A is intermediate between the other two in many characters, and in others it is nearly like one or the other, so that it may be only an intermediate form, but if so it is none the less definite, and as much a distinct type as either of the others. I am inclined to believe that this is one of the primitive forms from which the Igorots are derived, because of the broad nose, short stature, and long, low head which associate this type with the australoid peoples.

It will be necessary to compare the average Igorot with the three selected types in order to determine to which the Igorot is more closely related.

The truest anthropomorphic characters should be contrasted to show this; therefore stature, cephalic index, nasal index, relative forearm length, brachial index, and omphalic index are selected for comparison.

Type.	Stature	Cephalic index.	Nasal index.	Relative forearm.	Brachial index.	Omphalic index.
M	164.5	74.4	96.0	14.4	74.6	43.4
A	146.6	75.1	97.7	14.2	75.1	39.0
N	150.3	84.3	89.4	14.8	80.0	40.9
Average, Igorot	154.0	78.0	92.7	14.4	76.2	41.1
Average, M, A, N	153.8	77.9	94.4	14.5	76.6	41.1

The average Igorot resembles N more than M or A in stature, nasal index, and omphalic index, but is more like M and A in cephalic index, relative forearm length and brachial index, in which M and A are nearly alike. If M, A, and N each have had an equal influence in the composition of the average Igorot, then the average of the three should equal the average Igorot. If these two averages are different then the direction of the average M, A, N away from the average Igorot, and toward one or the other of the individual types, will indicate the direction of greatest influence. For instance, the average Igorot nasal index is 92.7 and the average nasal index of M, A, N is 94.4 which is nearer the nasal index of N than of M or of A. Therefore, the influence of N on the nasal index has been stronger than both of the other types. The same is not true of the stature, cephalic index and omphalic index for the averages are the same, hence the influence of each is equal. The influence of type N, however, has been greater than the other types in the relative forearm length and the brachial index. The average Igorot, therefore, has been molded in his makeup more by type N than by the others, at least in nasal index, relative forearm length, and brachial index.

Type N resembles the Negrito of the Philippines more closely than it resembles any other people and is clearly related to it, if not an actual prototype. The Negrito(48) is brachycephalic, type N is brachycephalic. The Negrito is platyrhine, type N is platyrhine. The Negrito has relatively long arms, type N has relatively long arms and forearms too. The average Negrito stature is less than 150 centimeters. That of type N is 149.5 centimeters. The hair of the Negrito is kinky, but that of type N is straight.

Type M is related to the European in so many ways as to leave no doubt of its origin.

Type A, with its long, low, flat head, broad face and wide, flaring nostrils, its very small stature and low omphalic index represents not one type but two. Compared with Martin's Senoi it shows many similarities, and when the two are compared with type N, the Senoi appears as if it were a blend of type A and type N. In stature the Senoi is between A and N, but nearer the latter than the former.

Comparison of types A, Senoi I, and N.

Type.	Stature.	Cephalic index.	Nasal index.	Relative arm.	Relative leg.	Relative forearm.	Brachial index.
A	146.6	75.1	97.7	43.6	51.2	14.2	75.1
Senoi I	149.5	80.0	85.8	43.9	52.1	14.0	76.0
N	150.3	84.3	89.4	44.9	51.2	14.8	80.0

The cephalic index of the Senoi is exactly intermediate between the other two. The nasal index is less than either of the others, and is nearer N than A. The relative arm length of the Senoi is between the two, but nearer A than N. The relative leg length of the Senoi is greater than either of the others, but this may be due to a difference in methods of measurement. Martin used the pubic height and I the trochanter height. The relative forearm length of the Senoi is less than the other two, but the brachial index is in between and nearer A than N.

These standard measurements place the Senoi in a somewhat intermediate position between type A and the Negrito. The hair of the Senoi is frequently wavy, which is an additional indication of Negrito blood. The Senoi of Martin(42) has a characteristic Negrito ear. The position of the Senoi in the Malay Peninsula, between the Semang (Negrito) of the north and the Malay of the south would indicate that they represent a mixed race, the result of the blending of two others.[3] Martin has unconsciously revealed a new race which is not the Senoi, but enters into their composition and is the same as type A.

Skeat and Bladgen(54) find three races in the Malay Peninsula: Semang, classed as Negrito; Sakai, or Senoi who are dolichocephalic, wavy-haired, and taller than the Semang, but have been modified by the Semang on one side and the Malay on the other, the latter people constituting the third race. The Sakai may be regarded as Dravidian, and so allied to the Veddahs of Ceylon, or as related to tribes in the interior of Camboge.

Martin associates the Senoi with the Veddahs, and the latter are closely related to the Igorots. The average stature of the Veddahs is 153.3, of the Igorots 154. The Veddahs are ortho-dolichocephalic, the Igorots, hypsi-dolichocephalic. The nose and face of the Veddahs are not so wide as the Igorot's, and the arms are 47 per cent of the body length, while the Igorot's are but 44 per cent. The Veddahs have straight or wavy hair, while the Igorot hair is almost invariably straight, although an occasional wavy-haired individual may be found(71).

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[3] Dr. Barrows, Director of Education, who has made an extensive and intensive study of the Filipino peoples, tells me that the three types described by Martin are to be found in different localities in the Philippine Islands, and represent the Negrito, the Malay, and a blend of the two.

P. W. Schmidt(51) compares the Indian, southeastern Asiatic (Mon Khmer Völker) and the inhabitants of the Malay Peninsula in physical characters and language, and concludes that the "Mon Khmer Völker" are intermediate between the others not only geographically but physically and philologically. The Indians are uniformly dolichocephalic, the Mon Khmer are dolichocephalic, mesocephalic and brachycephalic, and the Senoi are mesocephalic. The nasal index of the Indian is mesorhine and platyzhine, the Mon Khmer are leptorhine, the Senoi are mesorhine. The Indians are tall, the Senoi are small. The language, however, is the basis of Schmidt's argument that the "Mon-Khmer Völker" represent a link between the people of India and Oceania, or as he expresses it: "ein Bindeglied zwischen Völkern Zentralasiens und Austronesiens." The works of Keane(21), of Risley, of Lapicque(23) and others support this view.

One may go even farther than this, and select European types that are represented throughout the East among the aborigines. Three or more primitive European types may be segregated among the Filipinos of almost any part of the Islands by careful selection, and at least two of these are represented among the Igorots, one in type M and the other in type A. In each type the European has crossed with the Negrito, and the result is two entirely different types.

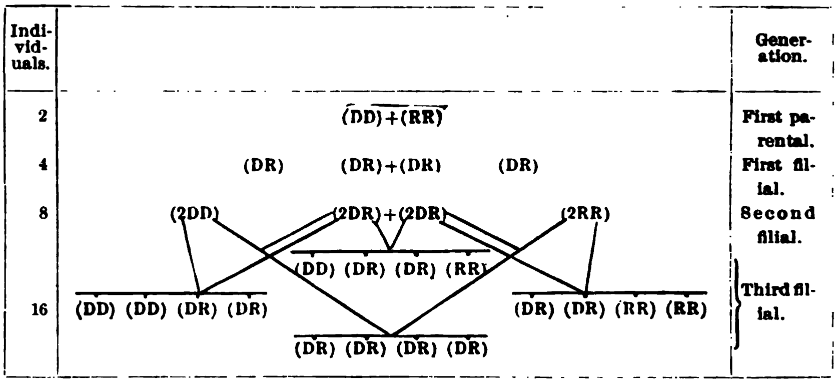
The European represented by M was a medium sized, stockily built individual, with straight, heavy nose, long, square head, straight, black hair, and oblong ears. These traits have persisted with the alteration of skin-color, face and nose width, and stature due to the Negrito. The nearest living related type to this primitive European is the "big cerebellumed, box-headed Bavarian of Ranke"(6). This type is present largely in the Spanish population of the Philippines, the data on which I base this statement being reserved for future publication. Type M, or near relatives of it, may be found wherever the so-called Malay has settled and represents a distinctive Malayan type.

The European represented by A was a small individual with long low head; black, straight hair, and round, flaring ears. The present European prototype is the Iberian, or Mediterranean race of Sergi. The union of these traits with the Negrito resulted in a small, dolichocephalic, broad-nosed type. The mingling of types M and A with the Negrito and their recent contact with the Negritos of the Philippines produced the Igorot (M, A, N). The process of amalgamation has been a long one, and it is not yet complete. The European migration eastward was in early prehistoric times, probably Paleolithic, when the types of white men were more distinct than at present, yet fewer in number and not so differentiated. Any hypothesis to explain the amalgamation of three different types, and the production of the Igorot by this amalgamation, presupposes at least three things: The segregation of unit characters in allelomorphic pairs, the dominance of one unit character in each pair, and the apparent disappearance of the other unit character. For instance the head of the Iberian is dolichocephalic, that of the Negrito is brachycephalic. The head of type A is dolichocephalic, and in order to account for this it is necessary to consider the broad head and the long head as unit characters of an allelomorphic pair, with the long head dominant. So the nose of the Iberian is leptorhine, that of the Negrito platyrhine; and the nose of type A is platyrhine, therefore, the wide nose is dominant. Many factors, such as environment, natural and sexual selection, the relative number of each type which enter into the amalgamated product, the time during which amalgamation has progressed, etc., exert an influence that must be reckoned with(58).

The broad nose of the aboriginal persists by sexual selection. The long head of the Iberian with greater mental capacity than the Negrito persists by natural selection. In order to illustrate the amalgamated condition of the Igorots at present I have prepared a simple diagram (fig. 13) to supplement my theory of heredity(5).

VIII. A SUPPLEMENTARY THEORY OF HEREDITY.

When dominant and recessive meet in equal numbers the proportion in the second generation is 3 dominant to 1 recessive, and this proportion remains the same in future generations.



Hardy(16) has demonstrated by simple mathematics, that a dominant character such as brachydactyly would not tend to increase in a mixed population after the second generation, in the absence of counteracting factors. Were Mendel's laws continuous in their operation throughout the life history of an endogamous people who represent two elementary species crossed, then one would expect the two to remain distinct and in definite proportions. But suppose Mendel's laws act for only a limited time, after which blending begins, then in the course of time the two elementary species would disappear by becoming absorbed in the blend, and a variable blend would result, the individuals representing every grade of difference between the original types. The blend may even become so perfect as to form a new elementary species if time is long enough and inbreeding sufficiently strong. The new species may be unlike either of the original and not a perfect blend of the two because of dominant factors and through extraneous influences.

The accompanying diagram illustrates my ideas in several ways. (Fig. 13.)

Point 1 is where the two types meet. Between this and point 2 there is true Mendelian heredity. At point 2 blending begins, and continues afterwards. From point 1 to point 3, spurious Mendelian heredity exists, because the blend continually crosses with the other types and creates endless confusion. Between points 3 and 4, no Mendelian heredity is found, but two tendencies exist, the persistence of type and the tendency to fuse. The diagram shows at a glance the relative number of each type at any given time.

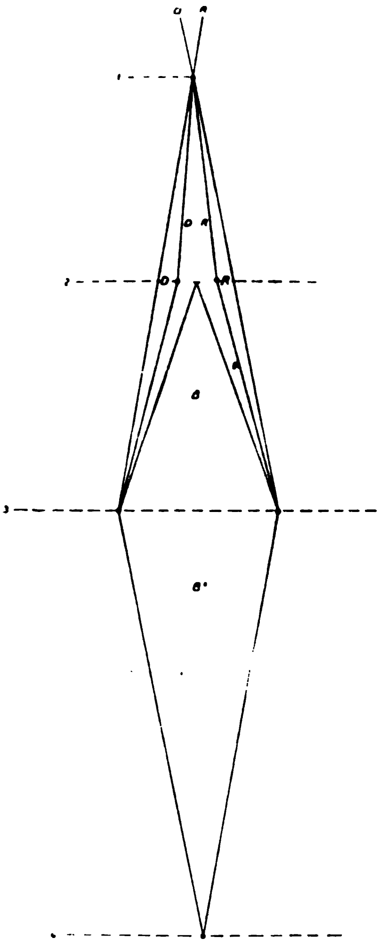


FIG. 13.—Scheme to supplement my theory of heredity.

In order to apply this scheme to the Igorot it is necessary to consider that three elementary species have united. First the Iberian and the Negrito blended and were in the condition of no Mendelism represented by type A or by the Senoi; then they were joined by type M, which was also in the condition of no Mendelism, resulting from the fusion of the Bavarian and the Negrito. The fusion of types M and A was in progress when the Negrito was again encountered since the arrival of the Igorots in the Philippines. The mingling of the types was probably more frequent than I have represented it, the crossings and recrossings more complex, and out of the moil of men through ages is evolved the Igorot.

A definition of elementary species which is of interest in this connection has recently been given by Spillman(55). This author illustrates clearly by a field of corn that each elementary species is "merely a cross section of a real variable species, and that the major part of variation is accounted for simply as a result of the recombination in each generation of Mendelian characters, each of which may vary between wide extremes, just as a species varies under the Darwinian theory of evolution. Under this view, a so-called elementary species is simply a completely homozygous form, which necessarily reproduces itself with absolute fidelity (my perfect blend).[3] The results secured by a breeder of so-called elementary species are a necessary result of Mendelian behavior of Darwinian characters."

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[3] Inserted by the author.

The measurements of a few individual Igorots are given to illustrate the combination of different characters in single individuals.

Name.	Height.	Cephalic index.	Nasal index.	Facial index.	Ear index.	Skin.	Nose.	Age.
Uabang	142	76	95	80	58	Brown	Australoid	33
Occi	146	82	83	73	57	Light brown	Aquiline	18
Obal	150	86	93	76	51	Brown	Australoid	65
Añoka	158	73	72	71	49	do	do	37
Mora	158	78	95	80	53	do	Aquiline	35
Peso	158	86	95	73	48	Dark brown	Australoid	25
Na-Ñgis	168	74	93	78	50	Brown	do	50
Palasi	168	72	95	84	48	do	Aquiline	45
Canutu	170	80	82	81	54	Light brown	do	24

Three small Igorots, three tall Igorots and three medium-sized Igorots are selected. One of the small men is dolichocephalic, one is mesocephalic and one is brachycephalic; the same is true of the medium sized, but two of the tall are dolichocephalic and one is mesocephalic. One individual in each trio has a narrow nose, whereas two in each have very wide noses, and a similar condition is true of the face and of the ear. One tall and one small individual have light brown skins, and one aquiline nose is present in each group. The Igorots are not yet completely fused in all characters, although the fusion is more marked in some characters than in others. Uabang represents type A, Obal the Negrito, while Oci is neither. Palasi represents type M, to which Na-Ñgis approaches closely, but from which Canutu diverges, although the tallest of the three; Anoka, Mora and Peso represent blended types.

Finally, the exact measurements of two Igorots and an American are placed together for comparison.

Comparative measurements of 2 Igorots and a Caucasian man (the first two were measured at the same time and place).

Measurement of—	Igorot (Martin).	Caucasian.	Igorot (Mora).
	cm.	*cm.*	*cm.*
Height	152.8	172.0	157.7
Shoulder	126.6	142.0	129.8
Umbilicus	90.0	104.0	92.5
Pubis	75.6	82.0	78.4
Knee	40.8	47.0	42.4
Upper arm	30.4	31.0	31.1
Forearm	21.9	22.5	22.3
Hand	17.8	19.5	16.1
Head length	19.6	19.7	19.2
Head width	14.8	14.6	14.9
Head height	13.2	13.0	13.4
Forehead width (narrowest part)	10.1	10.4	10.4
Bizygomatic	13.6	13.7	14.2
Chin-nasion	11.1	11.3	11.4
Width of nose	3.5	3.4	4.0
Length of nose	4.4	4.6	4.2
Between eyes	3.3	3.4	3.5
Age	45	40	35?

The simplest explanation of all the phenomenal variations heretofore presented seems to be that the Igorot has been isolated long enough to reach the amalgamated stage of no Mendelism.

The unit characters in all individuals have not blended, but occasionally manifest the character of the original type in a diversified way as represented by the nine Igorots, and not infrequently an individiual of almost pure type appears, who is a true European (Martin). These are but relics of a departed Mendelism.

Efforts to reconcile Mendel's laws with the prevailing views of blended effects in heredity need not be unavailing, if the two may be considered as phases of the same process acting at different times during the life history of an elementary species.

Heredity represents all the changes of organic life by three factors(5):

1. *Determinants,* which are in the germ plasm;
2. *Modifiers,* which are all influences through time and space that act on the germ plasm; and
3. *Laws of change,* which are the rules of conduct by which the determinants and the modifiers interact.

These factors are variable when looked at through all space and during all time, but for any elementary species in a given space and for a limited time they are fixed.

D and R (fig. 13) represent homozygotes of an allelomorphic pair that meet at 1 in sexual union, begin to blend at 2, present the picture of a variable blend at 3, and fuse completely into a perfect blend at 4. A cross section of the diagram above line 3 represents the relative number of individuals of the different kinds presert at that time. The width of the diagram also indicates the amount of variation at any time. D=homozygous dominants; R=homozygous recessives; DR=heterozygotes; B^1=a variable blend ever increasing in number with each successive generation; while D, R, and DR decrease to disappear entirely at 3. B^2 represents the continuation of the blend without either of the originals of the allelomorphic pair, but with all shades of intervening characters blending in various ways as influenced by ancestry and by enviroment, until a homozygote is formed at 4.

From 1 to 2 true Mendelism exists, spurious Mendelism is found from 2 to 3, and from 3 to 4 no Mendelism is present but two tendencies prevail, (*a*) the reversion to type, and (*b*) the tendency to blend.

The three Mendelian (?) conditions may exist at the same time in a single individual, one character exhibiting true Mendelism, another false and a third no Mendelism, or only one condition may be present at one time.

Davenport and Davenport(13) have established true Mendelian heredity for eye color in man; Bateson(2) has designated many conditions in man which indicate spurious Mendelism; and Boas(7, 8, 9, 10) has suggested the two hereditary tendencies above mentioned (*a* and *b*) when broad headed and long headed or wide faced and long faced individuals are united in marriage.

My records of negroes(3), of white students(4), and of the Filipinos suggest that composite types (elementary species?) of men when crossed with opposite types follow the laws of Mendel for not many generations, then begin to blend, and eventually fulfill the requirements of my scheme delineated above. At present all mixed races are probably in a condition of spurious Mendelism or no Mendelism. Among the negroes in America the Hottentot is rarely seen, the Kaffir is often encountered, and the Guinea Coast negro is abundant, but the majority of the negro population represents a variable blend of different negro types, and a large number of mixed bloods. Among 1,000 students at Ann Arbor I observed a few of each of the types of Europe, such as the Iberian, Northern, Alpine, Celt, Littoral, and Adriatic, but the majority of the students were variable blends, and the pure types were not exactly like the prehistoric types of Europe from which they were probably derived, although similar to them in many ways. During the past year my anthropometric investigations have included the Filipinos of many provinces, but especially the Igorots. Here as elsewhere pure types are rare and blends are plentiful. Three primary types are found among the Igorots. However, none of these are pure, but one type resembles the Negrito, another, one of the prehistoric types of Europe, while the third is unlike either of the others, but not a blend of the two. The majority of the Igorots represent a variable blend, and they have been so long isolated that a condition of no Mendelism has been reached. There is conclusive evidence of the persistence of type, yet the tendency to blend is emphatic.

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(59) Topinard, Paul. Éléments d'Anthropologie Général. Paris (1885), 1-1157. Adrian Delahaye et Émile Lecrosnier.

(60) *Ibid.*, 420.

(61) *Ibid.*, 431.

(62) *Ibid.*, 465.

(63) *Ibid.*, 998.

(64) *Ibid.*, 1003.

(65) *Ibid.*, 1006.

(66) *Ibid.*, 1082.

(67) United States Military Science and Tactics.

(68) von Török, Aurel. Versuch einer systematischen Characteristik des Kephalindex, *Arch. f. Anthrop.* (1906), **4**, n. s. 110–129.

(69) Worcester, Dean C. The Non-Christian Tribes of Northern Luzon, *This Journal* (1906), **1**, 791–877.

(70) *Ibid.*, 819.

(71) *Ibid.*, 834.

(72) *Ibid.*, 835.

(73) *Ibid.*, 845.

(74) Worthington, R. On Professor Pearson's Contributions to Osteology, *Journ. Anat. & Physiol.*, London (1901).

ILLUSTRATIONS.

PLATE I. (Frontispiece.) Dress of a typical Bontoc Igorot of the better class.
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III. Three types of Igorot noses. From left to right aquiline, straight, and australoid.
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VIII. Negritos with typical Negrito ears.
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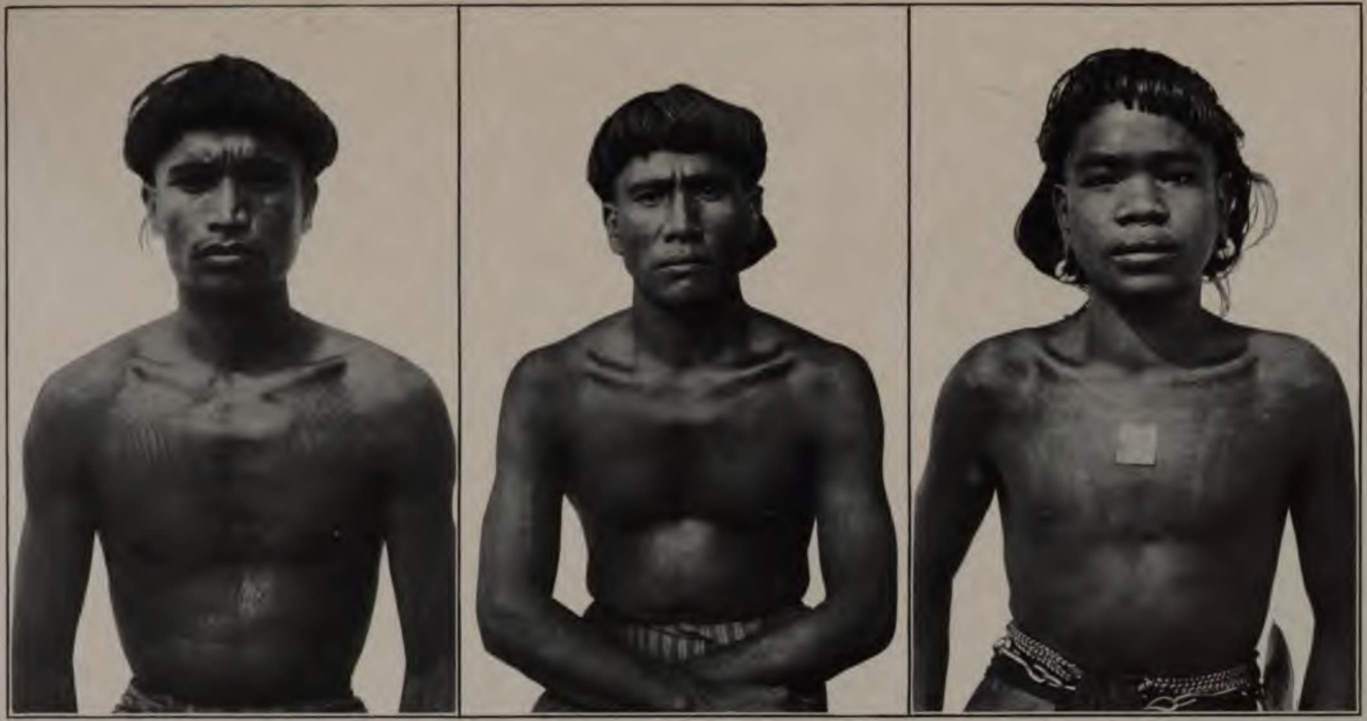

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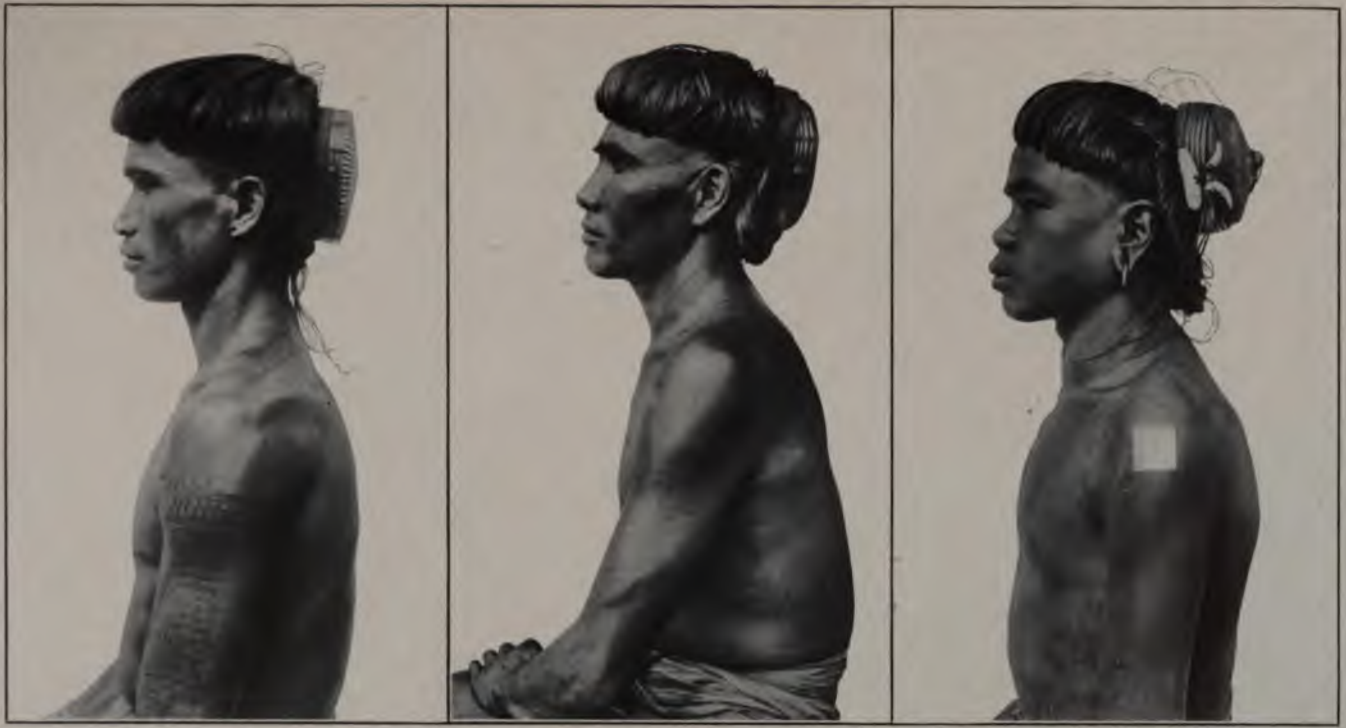

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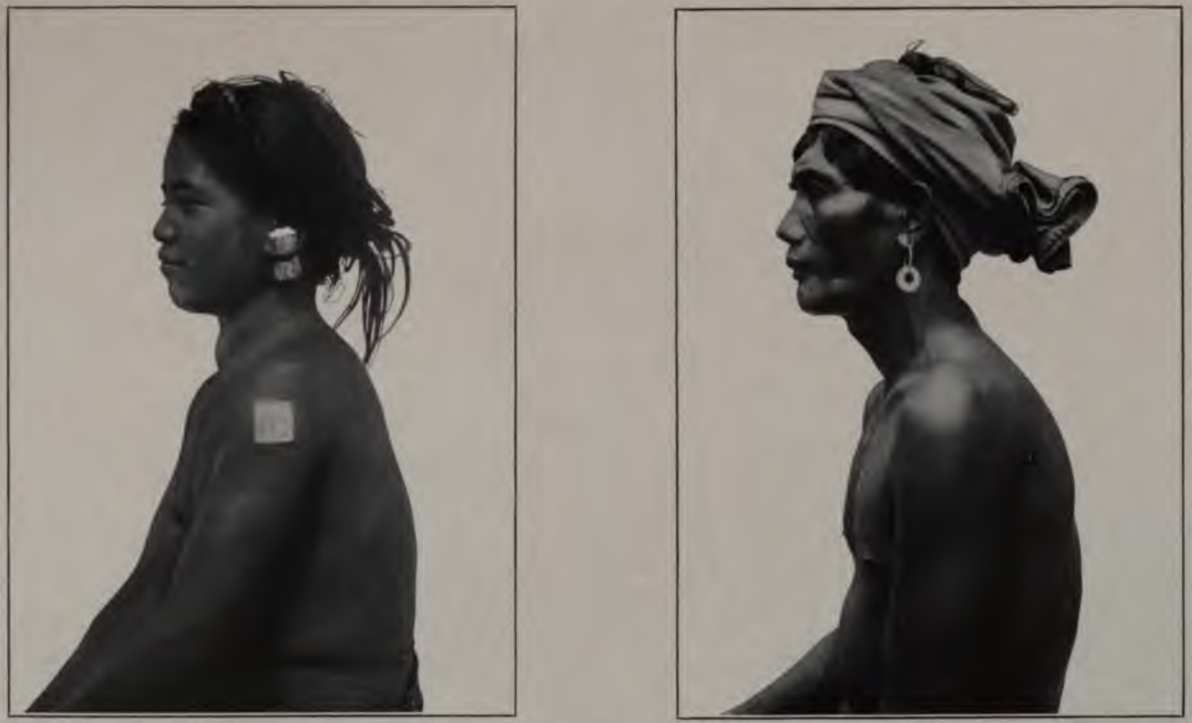

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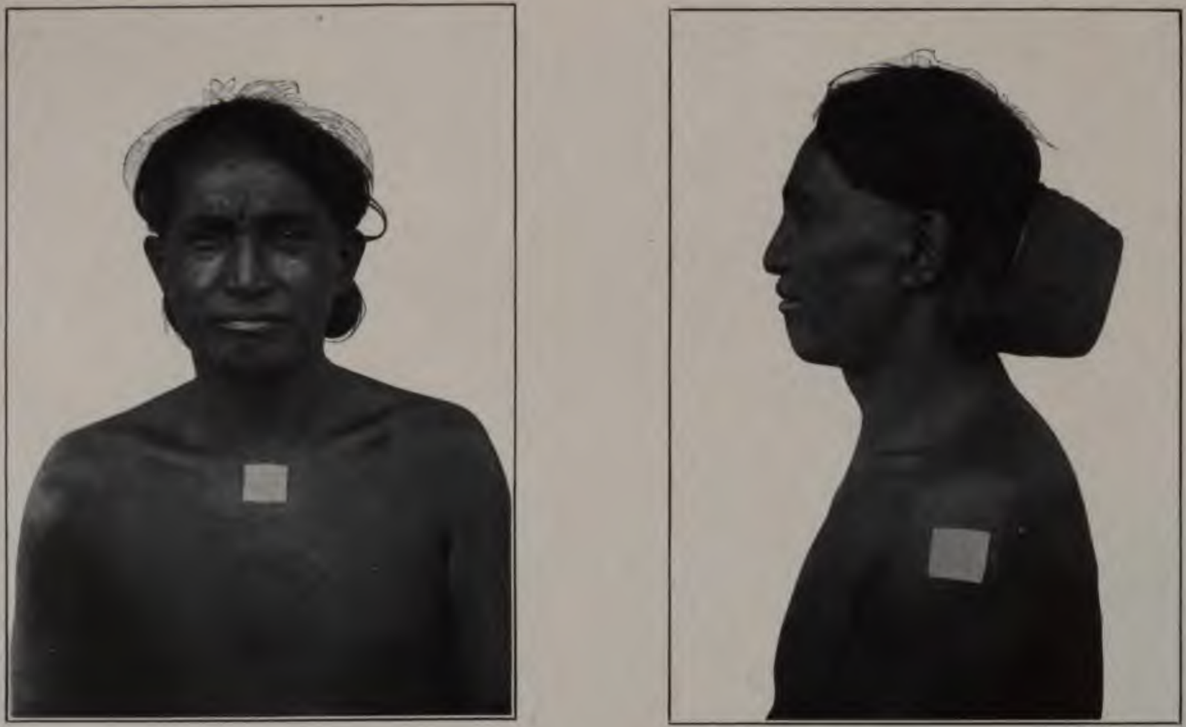

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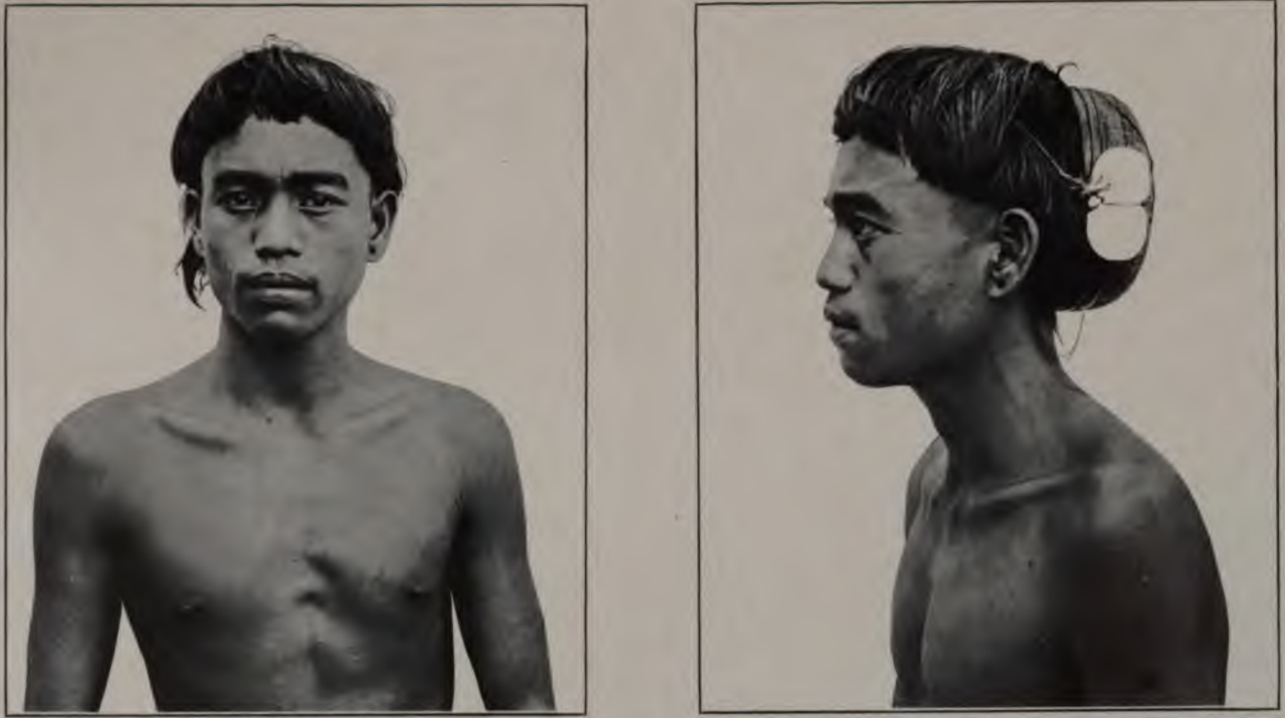

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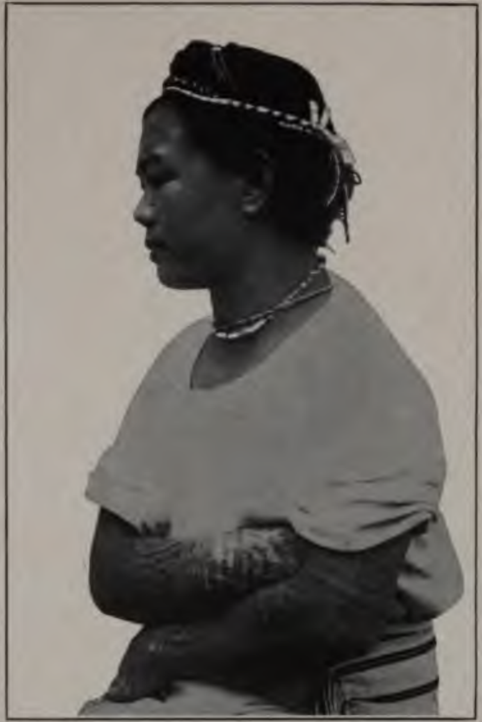

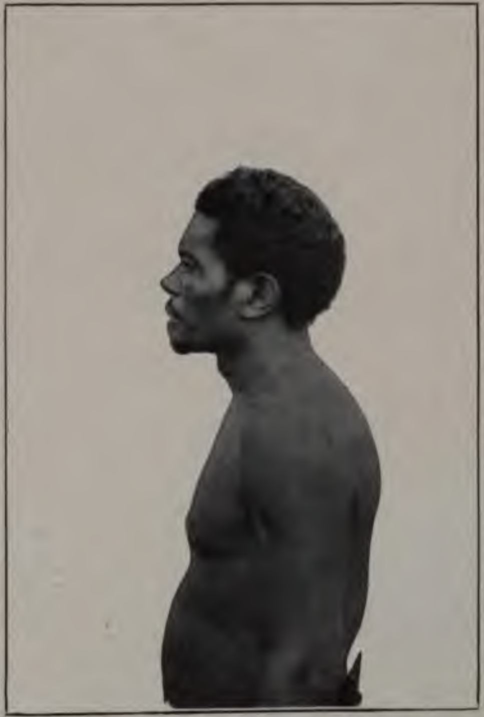

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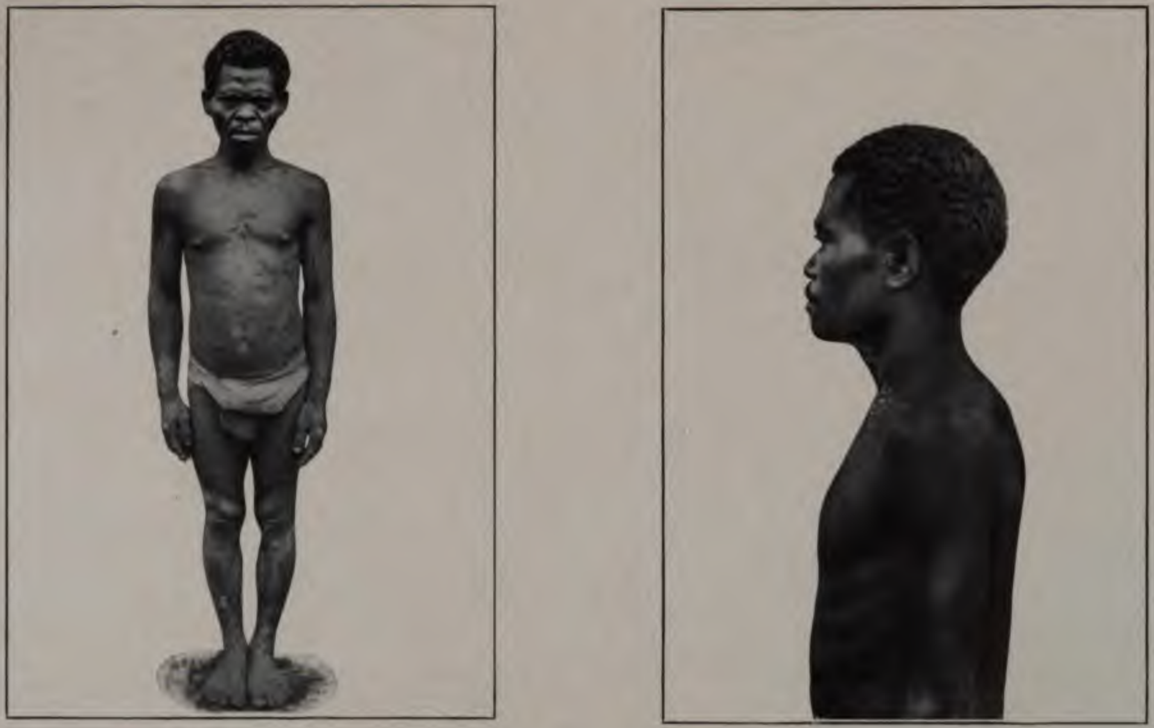

PLATE VIII.

TABLE I.—*Nativity.*

Average age.	Nativity.		♂	♀	Total.
20	Lepanto-Bontoc: Remote and inaccessible		15		15
33	Highland: Mountains and inaccessible	Atoc (2,000 m.)	42	10	73
		Tublay	21		
		Capangan			
22	Lowland: (*a*) Valleys and open country	Kabayan	9		30
		Baguio	8		
		Trinidad	6		
		Buguias	5		
		Daklan	2		
	(*b*) Baguio and vicinity	Bulalacao	4		27
		Lukbar	2		
		Cayapa	1		
		Balili	1		
		Loo	1		
		Others	18		
26	Total				145

TABLE II.—*Stature, in centimeters (adults).*

	Number.	140.	142.	144.	146.	148.	150.	152.	154.	156.	158.	160.	162.	164.	166.	168.	170.
Bontoc Igorots	14	----	----	----	----	1	----	----	2	2	2	1	1	3	2	----	----
Atoc	30	----	1	1	1	2	3	7	1	2	3	3	2	2	----	1	1
Tublay-Capangan	16	----	----	----	----	----	3	----	5	4	1	1	----	1	----	1	----
Total, mountain and inaccessible	46	----	1	1	1	2	6	7	6	6	4	4	2	3	----	2	1
Kabayan	5	----	----	----	----	2	----	2	----	1	----	----	----	----	----	----	----
Buguias	5	----	----	----	----	1	1	----	1	----	----	----	2	----	----	----	----
Trinidad	5	----	----	1	----	----	1	1	----	1	1	----	----	----	----	----	----
Baguio	5	----	----	----	----	----	1	----	1	----	1	1	1	----	----	----	----
Daklan	2	----	----	----	----	1	----	----	----	1	----	----	----	----	----	----	----
Total, river valleys	22	----	----	1	----	4	3	3	2	3	2	1	3	----	----	----	----
Baguio and vicinity	22	----	3	----	4	----	5	3	3	2	----	1	1	----	----	----	----
Total, adult Igorots	104	----	4	2	5	7	14	13	13	13	8	7	7	6	2	2	1
Females	10	135	1	----	4	----	1	----	3	----	----	----	----	----	----	----	----

TABLE III.—*Stature, in centimeters (adults).*

Nativity.	Number.	Mean.	Minimum.	Maximum.	Mode.	Median.
Lepanto-Bontoc	14	158.6	148.0	166.0	164.0	159.0
Highland	46	154.9	142.0	170.0	152.0	154.0
Valley	22	153.6	144.0	162.0	148.0	152.0
Baguio and vicinity	22	149.1	142.0	162.0	150.0	150.0
Total	104	154.0	142.0	170.0	150 0	153.0
Adult negroes of America	186	--------	151.0	195.0	165.0	168.0
Higland women	10	146.7	135.0	154.0	146.0	146.0
Bontoc (Jenks)	32	160.3	144.0	183.0	--------	--------

TABLE IV.—*Comparison of stature with age (males).*

IGOROTS.

Age.	Number.	Mean.	Minimum.	Maximum.	Mode.	Median.
5	2	97.0	92	102	--------	--------
6 to 9	2	121.0	114	128	--------	--------
10 to 11	7	122.5	114	126	--------	124
12 to 13	6	133.3	130	138	--------	133
14 to 15	13	141.9	134	158	141	142
16 to 17	8	152.7	148	162	152	152
18 to 19	19	150.0	142	162	146	148
20 to 29	43	156.0	148	170	156	156
30 to 39	18	155.3	142	162	154	154
40 to 49	10	155.0	144	168	154	154
50 to 59	3	161.0	156	168	--------	160
60	1	160.0	160	160	160	160
66	1	150.0	150	150	150	150

AMERICANS.[a]

Age.	Number.	Height.	Age.	Number.	Height.
5	208	105.78	13	515	145.09
6	410	110.67	14	485	151.02
7	544	115.69	15	327	158.18
8	565	121.31	16	218	163.73
9	546	125.86	17	512	169.98
10	496	130.95	18	723	171.07
11	660	134.90	19	796	171.81
12	559	140.29	20	736	172.22

[a] Hastings, 8,245 individuals.

TABLE IV.—*Comparison of stature with age (males)*—Continued.

EUROPEANS.[a]

Age.	Height.	Age.	Height.	Age.	Height.
5	105.6	11	135.4	17	167.3
6	111.1	12	140.0	18	169.0
7	116.2	13	145.3	19	170.8
8	121.3	14	152.1	20 to 29	172.5
9	126.2	15	158.2	30 to 34	172.8
10	131.3	16	165.1	34+	172.5

[a] Topinard, 1,104,841 individuals.

TABLE V.—*Absolute length of upper arm (brachium).*

Group.	15.	16.	17.	18.	19.	20.	21.	22.	23.	24.	25.	26.	27.	28.	29.	30.	31.	32.	33.	34.	35.	36.	37.	38.	39.	40.	Total.
Bontoc													1	1	2	2	5	2	1								14
Mountains													3	10	8	13	4	4	2	1							45
Lowlands											1	8	9	8	7	6	2	3									44
Adult males											1	8	13	19	16	22	12	8	3	1						1	103
Women										1	2	3	1	0	1	2											10
Boys, 12 to 15						1	1			4	4	6	1	2													19
Boys, 10 to 12						1	1	2	1	1		1															7
Boys, 10 and less	1		1	1			1		1																		5

TABLE VI.—*Absolute length of forearm (antebrachium).*

Group.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	24.	25.	26.	27.	28.	29.	30.	31.	Total.
Bontoc								1		1	2	4	2	2		1					13
Mountain								1	5	13	13	7	2	2	3						46
Lowlands							2	2	8	7	7	7	5	2	1	1					42
Adult male							2	4	13	21	22	18	9	6	4	2					101
Women						1	1	1	2	3	1	1									10
Boys, 12 to 15						4		1	5	4	2	1	1		1						19
Boys, 10 to 12				1	2	2															5
Boys, 10 and less	1	1			1	2															5

TABLE VII.—*Absolute length of hand (manus).*

Group.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	Total.
Bontoc						1	2	2	3	4	1	13
Mountain			1	1	7	8	14	10	3	1		45
Lowland			1		6	10	11	6	4	4	1	43
Adult male			2	1	13	19	27	18	10	9	2	101
Women		1		2	1	3		2	1			10
Boys, 12 to 15		2	3	2	3	3	5	1				19
Boys, 10 to 12	1	1		1	2	2						7
Boys, 10 and less	1		3		1							5

TABLE VIII.—*Standard according to the canon of Fritsch.*

No.	Type.	Locality or race.	Author.	Modulus.	Upper head height.	Extremity; length.	
						Upper	Lower.
1	Protomorph	South American man	Stratz	6.50	=	+	=
2	Melanoderm	Negro man	do	7.25	−	+	+
3	Xanthoderm	Chinese man	do	7.50	−	=	−
4	Leukoderm	German man	do	7.90	−	=	=
5	Protomorph	Karaya maiden	do	6.66	=	=	=
6	Melanoderm	Dschagga maiden	do	6.80	−	−	+
7	Xanthoderm	Japanese woman	do	6.35	+	−	−
8	Leukoderm	Rhineland woman	do	8.00	−	=	+
9	Protomorph	Australian woman	do	7.11	−	+	−
10	do	do	Ranke	6.75	+	+	+
11	do	Papuan man	Stratz	6.70	=	+	=
12	do	Bushman	Deniker	7.10	(*)	(*)	(*)
13	do	Hottentot woman	Bonaparte	7.45	−	+	=
60	Metamorph	Igorot man	Bean	7.80	−	+	−
3	Protomorph	do	do	7.40	−	+	−
83	Metamorph	do	do	7.90	−	+	−

* Not given.

TABLE IX.—*The selected types: averages, and indices or relative factors.*

ABSOLUTE—AVERAGES.

Type.	Number.	Stature.	Width shoulders.	Head length.	Head height.	Forehead width.	Between eyes.	Eye width.
M	8	164.5	36.1	19.4	13.3	10.5	3.6	2.9
A	9	146.6	33.5	18.8	12.6	10.2	3.3	2.7
N	8	150.3	33.1	17.7	12.8	10.2	3.1	2.9
Senoi I	17	149.5		17.9	12.2	10.2	3.4	
Average Igorot	104	154.0	34.8	18.8	12.9	10.3	3.35	2.85

RELATIVE—INDICES.

Type.	Arm.	Leg.	Forearm.	Hand.	Brachial index.	Shoulder.	Cephalic index.	Nose index.	Ear index.	Artistic canon.	Lower face to total head.	Omphalic index.
M	44.3	51.9	14.4	10.8	74.6	22.0	74.4	96.0	52.8	7.4	29.4	43.4
A	43.6	51.2	14.2	10.8	75.1	22.9	75.1	97.7	55.8	7.0	29.8	39.0
N	44.9	51.2	14.8	10.7	80.0	22.0	84.3	89.4	55.6	7.2	32.6	40.9
Senoi I	43.9	52.1	14.0	11.2	76.0		80.0	85.8		8.00	30.0	
Average Igorot	44.0	51.6	14.4	10.5	76.2	22.6	78.0	92.7		7.1	31.0	41.1

A GEOLOGIC RECONNAISSANCE OF THE ISLAND OF MINDANAO AND THE SULU ARCHIPELAGO.

I.—NARRATIVE OF THE EXPEDITION.

By WARREN D. SMITH.
(*From the Division of Mines, Bureau of Science.*)

CONTENTS.

I. INTRODUCTION.
II. PREVIOUS INVESTIGATIONS.
III. GENERAL GEOGRAPHICAL DESCRIPTION.
IV. PEOPLE.
V. CLIMATE.
VI. THE NARRATIVE OF THE EXPEDITION.

I. INTRODUCTION.

The Mining Bureau of the Philippine Islands, and subsequently the division of mines of the Bureau of Science, has now been in existence approximately ten years and during this time its scientific employees have visited nearly every part of Luzon and the Visayas, but up to the present the large southern island of Mindanao has been neglected. The reason for this is twofold; work was necessary in other and more important fields and only recently have conditions been such that travel in the greater part of Mindanao has been possible without a regiment of soldiers, although even now it is necessary in many places to take a detachment of from three to twenty men, as the Moros are still disturbing the peace in certain quarters.

One or two localities on the coast were visited by members of the *Cuerpo de Ingenieros de Minas* during the Spanish régime and I shall allude more fully to their work in the following pages.

The existing dearth of information in regard to this island led me, as chief of the division of mines of the Bureau of Science, to undertake a general reconnaissance of Mindanao and the Sulu group. Such a general view is necessary for planning future systematic and more detailed study.

The following four objects were in mind in beginning this expedition: (1) The rapid reconnaissance of the geology; (2) the examination of

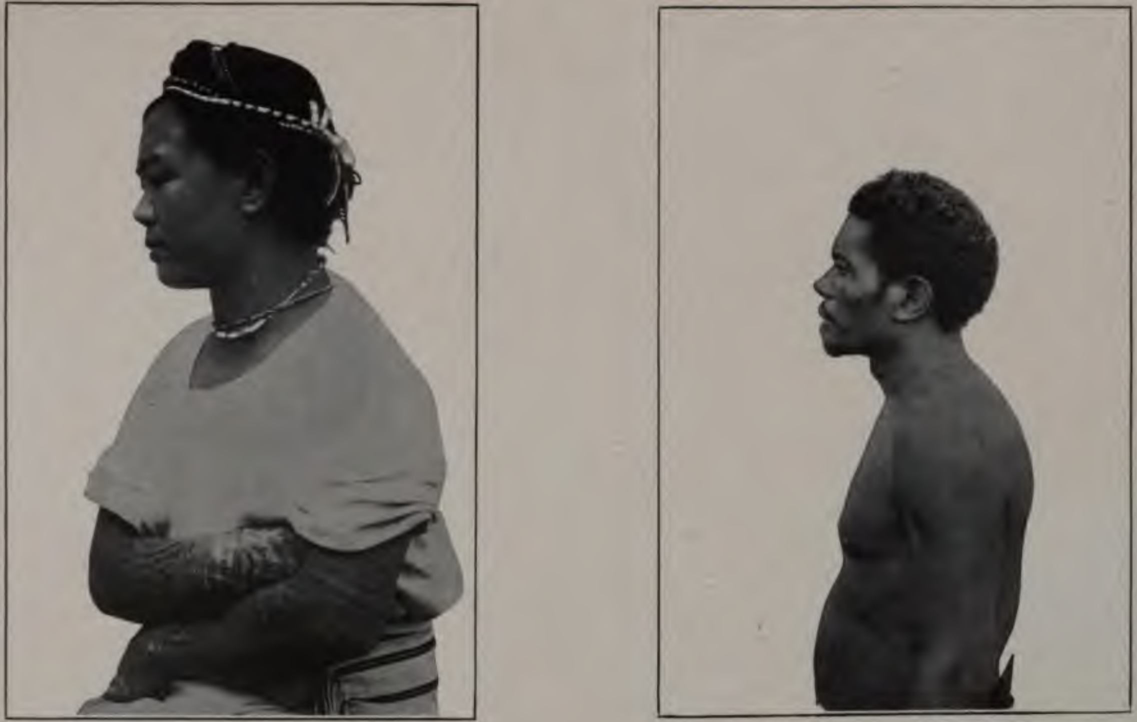

PLATE VII.

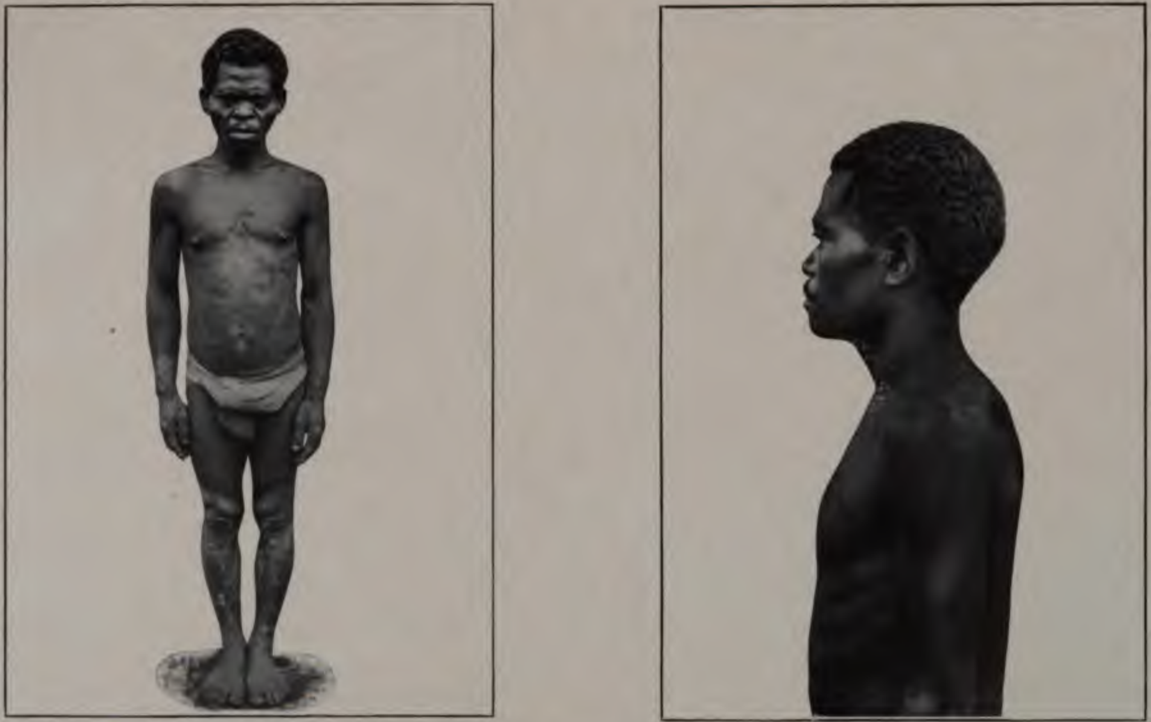

PLATE VIII.

and quartz porphyries. Melaphyre he found again at Pujada Bay near Cape San Agustin. Quartz breccias also occur on the divide between Pujada and the Gulf of Davao. Serpentine accompanies the melaphyre to the south of Bislig.[5]

"Mr. Minard visited the gold-bearing region of Misamis, the northwestern province of Mindanao. The sandstones and conglomerates of the Iponan Valley, dipping 12°, are said to be broken through at many points by diorite and serpentine. The pebbles of the conglomerates include diorites, augite-porphyry, serpentine, jasper, and marble.[6] Some years later Mr. Abella made a reconnaissance of this region, examining the gold deposits along the courses of several rivers, all of which empty into Macajalar Bay. They are the Iponan, the Cagayan, the Bigaan, and the Cutman. In this region he found two considerable areas of old slates. One of these touches the Iponan River 10 or 12 miles from the sea. The other is intersected by the Cutman and approaches the sea within 2 miles, near the town of Agusan, which lies at the mouth of the Cutman River. Alluvial deposits fringe the shore of the bay and follow the streams. Otherwise the country, as depicted by Mr. Abella, is covered with strata provisionally referred to the Miocene. The slates are described as metamorphic and in part steatitic. The pebbles of the Tertiary conglomerates consist of such slates, serpentinoid rocks, and many varieties of 'trachytic rocks.' I think that at the date of his memoir, 1879, Mr. Abella used this term for neo-volcanic rocks not basaltic in appearance. The description of the fossiliferous rocks overlying the slate leaves no doubt but that they are Tertiary or Recent, a fact which it is difficult to reconcile with Mr. Minard's statement that they are cut by serpentine and diorite. In the placer at the Bigtog, tributary to the Cagayan, Mr. Abella found slightly rounded, large pebbles of orthoclase.[7]

"A few miles northwest of Zamboanga (in southwestern Mindanao), at Caldera, Dana observed hornblendic and talcose schist in pebbles,[8] and on Malanipa, about 13 miles E. by S. from Zamboanga, the *Challenger* expedition collected serpentinized peridotite, studied by Mr. Renard."[9]

III. GENERAL GEOGRAPHIC DESCRIPTION AND ITINERARY.

The main body of the Philippine Archipelago is connected with Borneo by two parallel chains of islands, one consists of Busuanga, Linapacan, Palawan and Balabac, while the other extends southwest from the Zamboanga Peninsula, comprising Basilan, Sulu, Siasi, and Tawi-Tawi. The inference is that there has been entire land connection at some time in the past. This question will be referred to in a future chapter, at this place it is sufficient to state that there are some objections of a very reasonable nature to such a conclusion.

The Sulu Group and Mindanao together possess a rough likeness to a long-handled dipper, the Sulu Islands and Zamboanga Peninsula constituting the handle, the eastern part of Mindanao the bowl. Mindanao is marked by its great number of bays and gulfs, its two great rivers, its nine or ten lakes and its high mountains. One of the latter, Mount Apo, 2,928 meters, is supposed to be the highest peak in the Archipelago

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[5] Mission aux îles Phil. (1879–1881), 272–277.

[6] *Bull. Soc. géol.* France (1874), V, 2, 403–406.

[7] Mem. acerca de los criaderos auriferos . . . Misamis (1879), 4, 18, 32, 45.

[8] *U. S. Expl. Exp.* (1849), 10, 539.

[9] *Ibid.*

A glance at the map of Mindanao prepared by the Jesuits will reveal the presence of four main tectonic lines, three of which run approximately north and south, and the fourth east and west. The first is the line following the crest of the range which extends parallel to the long axis of the Zamboanga Peninsula; its direction is N. 20° E. The second seems most nearly to mark the eastward trend of this range; its direction is approximately N. 85° W. Along this line are to be found Mount Sugarloaf, just north of Dumankilis Bay, Mount Dapan, a short distance southwest of Lake Lanao, Mounts Kalatungan and Latukan east of the lake, and Mount Agtunganon east of the Agusan River.

The next line is that which follows the Apo Range. This is very pronounced from Apo southward, but is not especially marked to the north. On this line are to be found Mount Apo, 2,928 meters, and Mount Matutun, which is doubtless somewhat lower.

The fourth, which is not as straight as the others, extends along the backbone of the country east of the Agusan River; its general direction is about N. 8° W. No very important peaks exist along its extent.

The first of these four lines, which follows the backbone of the Zamboanga Peninsula, is the most marked in that it extends northward through the Island of Negros, coinciding exactly with the tectonic line of that island and cuts across the lower part of the prong of Masbate, again coinciding with the long axis of Sorsogon and the Catanduanes. The Agusan line, by curving a little to the west, would fit closely with the tectonic lines of Leyte, Masbate, and Tayabas. There is no question but that there is a definite and fairly uniform system of folding and fracturing throughout the Archipelago, the various islands representing the irregular crests of the anticlines while the intervening straits mark the synclines.

There are no very large rivers in the western part of Mindanao, although a fair-sized river follows along the central line of the Zamboanga Peninsula, and two short, swift streams also exist, one of them, the Agus, draining Lake Lanao and emptying into Iligan Bay after a run of about 30 kilometers, and the other, the Mataling River, drawing part of its water from Dapan Lake and part from the northern slopes of the Kulingtan Range. A different condition exists in other parts of Mindanao.

The *Rio Grande de Mindanao*, over 300 kilometers long, is the second largest river in the Philippine Archipelago. Its course is from north to south until within a short distance of Lake Liguasan where it turns sharply to the west, emptying into Illana Bay. This river is navigable for shallow-bottomed, stern-wheel steamers for a distance of over 200 kilometers. The valley of the Rio Grande presents a wonderful stretch of country.

The Agusan River, next in size, flows from south to north in a fairly uniform direction. It is probably at least 250 kilometers in length.

Mindanao in general is rather densely covered with jungle containing much fine forest. No large industries, unless it be agriculture, exist in the island, if one sawmill, erected by Americans not far from the town of Zamboanga is excepted. There are neither mines nor factories, the little that has been accomplished has, for the greater part been the result of the energy of a few Americans and Spaniards. For the most part this great and enormously fertile island is a silent, almost trackless jungle.

We can only conjecture what the mineral wealth of Mindanao really is, for few as yet have had the hardihood to attempt prospecting in this region.

IV. PEOPLE.

The distribution of the different tribes can be learned by reference to the map prepared by Dr. N. M. Saleeby [10] to accompany his researches into the life of these people. It is not my intention to discuss very fully the racial characteristics of the people inhabiting Mindanao, as Dr. Saleeby will do this fully and thoroughly. However, it will be necessary to make brief mention of the character of the inhabitants in this paper and to make this portion as accurate as possible I have not only drawn from personal observations, but more frequently from Dr. Saleeby's first work.[11] Other sources of information have also been used.

A line extending roughly from Iligan in a southeasterly direction to the Kidapwan Mountains and thence south to Sarangani Bay will divide the island into two great ethnological divisions. To the west of this line the Moros, a Mohammedan people, are dominant. To the east are various tribes which in all probability spring from Malay stock and who presumably came to Mindanao long before the Mohammedan invasion. The Sulu group to the south of Mindanao is inhabited almost entirely by Moros.

A considerable number of Visayans and a few Tagalogs, who have emigrated from the northern islands, are encountered along the coasts and at the mouths of some of the rivers.

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[10] Saleeby, N. M.: The History of Sulu, *Pub. Div. Eth., Bureau of Science*, Manila (1908), 5, 11. The map of Mindanao will be published in Dr. Saleeby's work "The History of Magindanao" now in course of preparation.

[11] Saleeby, N. M.: Studies in Moro History, Law, and Religion, *Pub. Eth. Sur.*, Manila (1905), 4, 1.

V. CLIMATE.

It is difficult to discuss the meteorologic conditions of Mindanao in a general way. The fairly regular and distinctly marked seasons which prevail in Luzon do not seem to obtain in Mindanao. The following table is taken from the monthly reports of the Philippine Weather Bureau:

Rainfall, in millimeters, at Mindanao and Sulu stations during 1905.

Month.	Zamboanga.	Isabela.	Jolo.	Davao.	Surigao.
January	8.7	13.2	38.1	79.0	105.3
February	2.6	1.5	0.0	121.4	101.1
March	0.0	0.0	22.4	206.2	81.9
April	37.3	9.6	0.0	88.4	130.6
May	143.5	102.4	305.0	417.8	176.9
June	25.3	54.0	19.6	192.8	0.0
July	214.6	140.2	209.9	341.4	167.8
August	84.1	112.4	38.9	328.8	112.0
September	62.6	145.3	229.6	160.6	216.8
October	148.2	320.9	420.4	127.8	112.8
November	107.7	112.8	59.4	66.5	380.4
December	57.7	91.2	69.6	----------	483.6
Total	892.3	1,103.0	1,412.9	2,129.7	2,068.7

A great difference is shown between the rainfall at Zamboanga, at Surigao and at Davao, and the results are very evident in the difference between the forests of these portions of the island. Zamboanga Peninsula is fairly well forested, if the plain which has been cultivated for a long time is excepted, but the forest of this region is not by any means as luxuriant as that of the Agusan and Davao Valleys. The densest forests in the Philippine Islands, with the possible exception of portions of Mindoro, are probably to be found in the latter districts.

I was not in the country for a sufficient length of time to render any statement I might make in regard to the healthfulness of various parts of Mindanao of value. The low country in the river valleys and the lake region to the south of the Cotabato is probably not as healthful as the highlands of the Lanao region. Mosquitoes abound in many parts of the former territory and great precautions must be taken against them. The Cotabato River has a particularly bad, but I think underserved, reputation in this respect. I had no fever nor any sickness whatever during the five months I was in Mindanao, but both native and American troops have suffered considerably from malaria.

A table of the temperatures for the various stations of the island follows:

Table showing mean maximum and mean minimum temperatures, in degrees centigrade, for Mindanao stations during 1907.

Month	Surigao.		Jolo.		Isabela.		Zamboanga.		Davao.		Cotabato.		Dapitan.		Butuan.		Carago.	
	Maximum.	Minimum.	Maximum.	Minimum.	Maximum.	Minimum.	Maximum.	Minimum.	Maximum.	Minimum.	Maximum.	Minimum.	Maximum.	Minimum.	Maximum.	Minimum.	Maximum.	Minimum.
January	29.6	21.8			30.9	21.5	30.3	21.8	32.2	22.5				23.1	28.4	21.3	30.6	21.8
February		22.4			31.3	21.9	30.3	22.3	31.7	22.3				22.6	28.6	21.7	29.5	21.9
March	29.6	21.6			31.6	22.2	30.9	22.8		22.6				23.6	29.4	21.9	29.7	21.7
April					31.4	22.0	30.6	23.0	32.7	23.0				23.6	31.0	22.2	30.5	22.0
May					31.6	22.8	30.6	23.3	33.0	23.0				23.6	33.0	23.3		
June	32.4	22.9			31.2	22.5	30.1	23.3	32.3	23.2				22.9	32.8	22.7	30.2	22.6
July	33.0	23.2			31.0	22.1	29.7	22.9	31.6	22.8	33.0	22.3		22.4		22.1	31.1	22.3
August					30.5	21.9	29.2	22.7	31.4	22.8	32.0	22.0		23.2		23.0	30.8	22.6
September			32.3	23.5	30.4	21.9	29.6	23.1	33.3	22.4	32.6	21.7		23.8	31.3	29.9		
October			31.8	22.3	30.2	22.4	30.8	22.9	33.0	22.4	33.6	22.2		24.1	30.3	22.5		
November			31.2	22.9	30.8	22.6	30.8	23.0	32.5	22.3	33.6	22.0		23.7	28.9	21.8		
December	28.3	22.1	30.9	23.2	30.6	22.6	29.7	23.0	30.9	22.3	33.2	22.1		23.3	27.9	22.2		

The region around Camp Keithley, owing to its altitude is much cooler than the low country and the climate is correspondingly invigorating. However, at certain times of the year, particularly in December and January these posts are said to be very disagreeable, as they are cold and raw like the New England coast of the United States in the spring time.

Typhoons are said not to occur in the latitude of Mindanao and the Sulu Islands. The evident reason for this is that the cyclonic storms, which have their origin in the Pacific are formed in a latitude much north of that of Mindanao and as they pass westward they are constantly curving to the north, partly owing to the original, clockwise movement of cyclones north of the equator and partly because of their approach to the continent of Asia. According to Father Algué, Director of the Philippine Weather Bureau, a few cyclones form in the Sulu Sea, but these attain no great importance either in frequency or in intensity.

Plate XXIX of Father Algué's "Cyclones of the Far East" [12] shows the mean trajectories of cyclones which pass over or near the Archipelago. It is very interesting in that it reveals how very generally Mindanao and the Sulu group escape these destructive storms. This fact is of the first importance in view of damage which such storms might inflict on crops, particularly on hemp which grows to heights varying from 10 to 18 feet, and because of the relative immunity from danger to vessels, such as interisland trading ships, Moro *vintas* and pearling boats.

VI. NARRATIVE OF THE EXPEDITION.

Zamboanga, the first point visited by me, is situated about 3 miles from the nearest foothills at the edge of a flat plain of considerable area at the foot of the long, narrow peninsula of the same name. (See map, Plate I.) To the east is a long stretch of salt-water marsh and in its rear is a scarcely less elevated tract which is taken up with paddy fields. If the Tumaga River had kept its initial direction, it would cut through the heart of the city, as it is, it curves to the east and enters the sea opposite Sakol Island. The substructure of this plain is coral, the superstructure, silt and coarse detrital material from the hills to the north.

Zamboanga is essentially a "gate city" and a study of the map will show its central, commanding position with reference to steamship routes. In fact this is the main feature controlling its location. It is not situated on a large river by which communication can be maintained with the interior and for this reason its position is not favorable as is that of Manila, which is on a plain on the coast and at the same time on the banks of a large stream which taps a great stretch of the interior. Cotabato, on the *Rio Grande de Mindanao*, is also favorably located and it will probably expand when the immense possibilities of the country to which it holds the key are understood.

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[12] **Algué, José:** The Cyclones of the Far East. Bureau of Public Printing, Manila, 1904.

The initial reconnaissance which I undertook was to Boalon, some 10 or 12 kilometers northeast of Zamboanga. Here the transportation by wagon was left and a trail taken which led up an abrupt hill a little beyond which point we entered the forest. Between Boalon and this hill I found some float limestone with fragments of *Orbitoides,* which probably are identical with the material Richthofen [13] encountered so many years before. This is practically all he contributed to the geology of this region, but this is not suprising when the attitude of the natives at that time is considered.

We continued in the forest for about three days, obtaining absolutely no view of the country farther than 50 yards from the trail, until we reached a log cabin about 30 miles north of Zamboanga on the Tumaga River.[14]

The country rock in this region is a much decomposed schist, with a considerable thickness of stiff, yellow, clay overburden. (Plate III.) Quartz pebbles and bowlders are plentiful in the clay; the pebbles come from quartz stringers in the schist. The large bowlders clearly indicate large veins, but we were not so fortunate as to encounter any of the latter. The clay contains a small amount of gold which the prospectors had recovered by sluicing. Few people were encountered in this forest.

On our return after three days' stay we followed the river for perhaps 25 kilometers. At times we came upon box cañons (some of which we might have swum through), but usually we took the high trail which went along the steep side of the cliff, at times 30 meters above the water and rocks. The way was extremely difficult; the sharp river rocks, the sharp-edged schists and the leeches began to tell on our carriers, so that we finally took a trail which led out of the river and after a climb up the side of the gorge we regained the old path which we followed to a hemp plantation at the edge of the timber and by mid-day arrived in Zamboanga.

VICINITY OF SAN RAMON.

My next reconnaissance was in the vicinity of the San Ramon Farm, controlled by the Moro Province. This excursion was for the purpose of an examination of the mountains which rise abruptly back of the narrow coastal plain. The formation in this place is entirely volcanic, the rich, disintegrated débris spreading out upon the coastal plain and producing a very fertile soil. Some of the rock is highly pyritized and may carry more or less gold.

In the streams I saw bowlders of andesite which sometimes contained large fragments of schist, torn off and caught up in the molten rock as it poured out over the surface. This schist is identical with that found in the gorge of the Tumaga River.

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[13] Richthofen, F. von: Vorkommen der Nummulitenformation in den Philippinen. *Zschr. d. deutsch. geol. Ges.* (1862), 14, 357.

[14] A sketch map of the trail was made, but it shows little beyond the path.

I had observed terraces along the shore farther to the north in the neighborhood of Dapitan and therefore looked for some signs of elevation here. I did find one fairly well preserved terrace a few miles to the north of San Ramon, but the streams have cut through it in so many places that only an especially trained eye can see it. This terrace is perhaps 6 meters above the mean tide level. (Plate VII.) The mountains in the Zamboanga Peninsula were once covered with a mantle of limestone, but little of the latter remains, a few large bowlders in the streams being all that we could find.

This coastal strip on which San Ramon is located, disappears to the north at Patalun Point, but it widens regularly to the south and is everywhere taken up with coconut culture. The long stretch of sandy littoral from San Ramon to Zamboanga is especially adapted to the culture of the coconut palm.

This peninsula in regard to its population might be divided into the following zones:

1. The hill or forestal zone occupied by Subanuns, a wild and primitive people.
2. The intermediate or rice zone by Filipinos, mostly Visayans.
3. The coastal plain by Chinese and Americans.
4. The beach zone by the Moros (littoral zone).

COAL MINES AT SIBUGUEY.

Following the reconnaissances outlined above I went to Sibuguey Bay, an all-night run by Constabulary vessel to the northeast of Zamboanga. I was accompanied on this trip by Colonel W. C. Taylor, then in command of the Fifth Constabulary District. We anchored about a half mile offshore as we did not know the exact configuration of the reefs, this coast being but incompletely charted.

Our road to the coal measures at Sibuguey was first by boat up the Siay River, the banks of which for some distance from the mouth are lined with mangrove swamps, we taking a turn through an opening in the right bank and following an estuary until noon, when we landed and followed a trail over a low hill to the house of the *datu* of this region, Lukas, a Subanun. (See Plate VIII.)

We left this place early in the afternoon and after a very trying march through mud and over hills, we reached the site of the coal workings on the Sibuguey River. The old, abandoned tunnels of the coal mines are hidden by the underbrush. I could obtain but little idea of the condition of the seams, excepting that they are tilted and dip to the southeast. They can be worked with the mine mouth probably not over 100 meters from the Sibuguey River, which is large enough at this point, 21 kilometers from the mouth, to allow small launches and lighters to pass up and down to take on coal.

THE SULU ARCHIPELAGO.

The Sulu Archipelago is practically unknown from a geologic and physiographic point of view, so that the information gained in this expedition, although meager, is at least new.

Dr. Becker refers in four lines of his report to rocks on Marongas Island just across from the town of Jolo. Other than this there are no geological notes. Some eruptions of the year 1614 are described by the resident Jesuits but only in a crude way. It has been known for a long time from the reports of ship captains and travelers that the archipelago is largely volcanic.

This great group of islands extends for 335 kilometers southwest of Zamboanga. It is about 120 kilometers wide and contains hundreds of islands and rocky shoals. The most considerable of the islands are Basilan, Sulu, Siasi, and Tawi-Tawi and although Basilan is the largest, Sulu is of far greater commercial and historic interest.

The water is nowhere of great depth within the confines of this archipelago, but it is separated both from Borneo and Mindanao by deep straits. To reconstruct a large island out of this swarm of small ones which may or may not have formed a continuous bridge from Borneo to Zamboanga, and which would since have been disrupted and partly submerged, is not a great tax upon the imagination. The evidence we have points in this direction.

The Sulu group, like so many other oceanic islands, is either of volcanic or coral formation. I saw very little sedimentary material on any of the islands and where any such was exposed, it was usually at a point where erosion had removed the lava capping. I do not know of any marked volcanic activity in the Sulu Archipelago at the present time, although hot springs in old craters are reported on Cagayan Sulu. I have also been informed that there are hot springs and solfataras at Si'it Lake on Sulu. This lake occupies an old crater. I have visited neither of these places.

An eruption at a point near Jolo, not named, is reported to have occurred on January 4, 1641.[15] As there is some confusion of names in this report I do not attach much importance to the account. As far as I can learn, no accurate scientific notes were taken at the time.

The only remaining reference I find regarding the geography or geology of the Sulu Archipelago is a note by Becker:[16]

> "In the Jolo Archipelago, the charts indicate several well-developed atolls, such as Simonul Island (latitude 4° 52', longitude 119° 50'), as well as several in the Tapul group (latitude 5° 30'). The charts of this region also show innumerable coral reefs, which are bare at low tide and must therefore have been uplifted."

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[15] Baranera, Francisco X.: Compendio de geografía de las Islas Filipinas, Marianas, Jolo y Carolinas. 3a ed. Manila, 1892.

[16] Geology of the Philippine Islands, 562.

I myself have seen some coral islands near Sulu, in the Pangutaran group; some of these are atolls and others were formerly lagoons that have dried up because of the elevation of the whole mass.

While nearly all the elevations are extinct or dormant craters, there are no sharp, jagged profiles, but instead, most graceful curves. There are nearly fifty of these cones on the Island of Sulu, some still high and symmetrical, others irregular and worn down to mere stumps. (See Pl. IV.)

BUD DAJO.

We first visited the now historic crater of Bud Dajo,[17] the wooded cone of which rises from the plain back of Jolo. One afternoon of brisk riding on horseback is necessary to reach the point where the very steep climb begins at 300 meters' altitude; from here to the extinct crater is a further elevation of 580 meters. The climb is a short one, but it is the most strenuous I remember ever to have made.

Formerly there existed a community on this mountain having all the necessaries of life about them; a complete village with dwellings and a mosque; springs, gardens, and both shade and fruit trees, all within an extinct crater. The Moros added trenches and *cottas* to the natural walls of the village and long bamboos, in the hollows of which were concealed *lantakas* (brass cannon) were placed along them. (See Plate X.)

Bud Dajo is formed of scoriaceous basalt and lapilli, but has not been in eruption at least within the last three hundred years, or if it has, there is no record of the event. Large basaltic bowlders from this mountain are strewn over the slopes and the plain down to the very edge of the town of Jolo. An excellent view of a large part of the island can be had from the highest point on the walls of the crater. From this point smaller craters are visible and it is not impossible that renewed energy may at some future time be manifested at one or more of the many foci and a considerable destruction of lives and property be the result. The fact that these craters appear extinct is no argument against future activity.

FURTHER RECONNAISSANCE OF SULU.

On Monday, October 14, Lieutenant Caffery and I, with an escort of five men, began an expedition to Maymbung, on the opposite side of the island. The trail led past Asturias, the former residence of the Sultan of Sulu, but now the site of infantry barracks, and on over a low divide of about 300 meters' altitude, between Bud Agad and Bud Pula. The soil is of a rich red color, giving promise of unusual richness. Large fields of tapioca, which is the main agricultural product of the

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[17] *Bud* is the Sulu term for mountain. As it is generally used by the military authorities, it is retained in this description.

Sulu Islands, appear on either side of the trial and Moro dwellings, with several small haystacks near by could be seen from time to time. However, large tracts of fallow land exist along the route.

The soil everywhere is the same, for a blanket of basalt apparently lies over the whole island. At Maden Patung, about a mile and a half from the Sultan's house at Maymbung, are some outcrops of tuff, the only sedimentary formation I saw while on the Island of Sulu.

We reached Maymbung late in the afternoon and the next day returned to Jolo by the same route we had come by, our stay being cut short by the consideration that a geological reconnaissance conducted under guard in a very unsettled country does not warrant the expense and the additional detail of men. "Such work is really more exciting than profitable."

Several short excursions in the vicinity of Jolo were made for the purpose of finding water-bearing strata, but in this respect the result was disappointing. However, some splendid examples of old, worn-down craters were seen. Several low, circular and apparently flat-topped hills lie at a distance of 3 to 5 kilometers southwest of Asturias. They very much resemble overturned saucers. The tops of these hills usually show a more or less marked depression, a remnant of the old crater, and two of these were inhabited by several families, with substantial houses and well-kept gardens. These people live in such situations, not so much because the soil is particularly rich, because it would be hard to find soil more fertile than that on the lower volcanic slopes, but undoubtedly because of the protection afforded by the hills, the comparative difficulty of access and the excellent lookout over all approaching trails. There is usually some water either in the central depression or at the bases of these volcanic mesas.

OTHER ISLANDS OF THE SULU GROUP.

I returned to Zamboanga after this brief visit to Sulu and reshipped on a small Constabulary paymaster-boat for the more distant islands of the Sulu group. The first stopping place was at the Island of Bongao. Tawi-Tawi was not visited, such observations as were possible being made while sailing near to the coast. It is not a very rugged island, everywhere showing gentle curves.

Bongao is a small village and Constabulary station on the island of that name, separated by a narrow channel from the southwestern end of Tawi-Tawi. Coral reefs are found everywhere in these waters, so that great care in navigation is necessary. Mount Vigia, visible from the dock (see Plate XIV), is a mass of very resistant conglomerate, 370 meters high, and on a clear day the low coast of Borneo can be seen from this peak.

Some raised beaches exist in this vicinity and a number of fossils of recent age, clearly Pleistocene, were procured.

From Bongao we navigated through a labyrinth of islands along channels so narrow as to make it almost possible to lean over the side of the boat and touch the branches of the trees, and we finally anchored in the narrow straits between Siasi and Lapac Islands. We had but one or two hours of daylight at this point, but a short excursion inland gave us a fairly good idea of the geology and soil of Siasi. The soil, as in Sulu, is a rich, red volcanic material, and the underlying rock, wherever I saw it, was andesite or basalt, which is frequently difficult to classify exactly, because of the weathering to which it has been subjected. Very little timber is seen on this island, at least not on the side at which we touched, and there are no large streams. However, a dense growth of cogon grass prevents serious damage from erosion. If this grass were not present, loss would surely result owing to the lack of forest. On the other hand cogon, as in other parts of the islands, is a serious menace to agriculture. It is usually the custom of the natives annually to burn off this grass, but this method only affords temporary relief. A better way and one which is being practiced with success in many localities is to plow the cogon under for two or three seasons, when the roots rot and not only is the grass killed, but the soil is further enriched.

The next point visited was the large and geologically little known Island of Basilan. A portion of this island was occupied by the Spanish government, which had a small naval station at Isabela on the north coast. This has been abandoned since American occupation and the place has consequently fallen into neglect and decay.

But little geographical exploration has been done in Basilan. Mr. Dean C. Worcester and his party visited it about the year 1892, and the following is taken from his account.[18]

"Isabela, the capital of Basilan, is a small place of less than 1,000 souls. The only Spaniards there are the officials and the Jesuit priest. The town is on high ground, which slopes sharply down to the edge of the channel separating Basilan from the little island called Malamaui. This channel, although extremely narrow, is very deep, and large vessels can come close inshore. Tremendous currents rush through it with the ebb and flow of the tides.

"Isabela is a supply station for gunboats, the coal yard and magazines being located in Malamaui, just across from the town. To defend the important stores which they contain there is only a ridiculous old limestone fort on a neighboring hill, armed with two or three antiquated smoothbore cannon, and garrisoned by a few marines.

"The Moros of Basilan, locally called *Yacans*, have always borne a bad reputation, but at the time of our visit they were held in check by a remarkable man known as *Datu* (Chief) Pedro."

A picture of the fort mentioned above is shown on Plate XV.

Only two short trips were made into the country back of Isabela; the same basaltic flows and rich red soils exist here as in Sulu and Siasi. Vulcanism does not appear to be as recent in Basilan as in Sulu. At no place did I find that the streams had cut through the lava capping and exposed the sediments which I feel sure lie beneath.

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[18] Worcester, Dean C.: The Philippine Islands and their People. Macmillan, (1901), 144.

LAKE LANAO AND VICINITY.

All of the work in the region of Zamboanga and the Sulu Archipelago which it was at all feasible to undertake at this time having been completed, we left Zamboanga, November 6, for Overton. As our vessel kept close to the coast, I was able to make some notes which throw considerable light on the geologic changes now going on. The west coast of Mindanao has very certainly risen in comparatively recent times. Near Point Blanca on the northwestern part of the coast I saw a fine example of a raised delta, the elevation amounting to at least 10 meters. The characteristic structure of the delta was clearly revealed by the extensive marine erosion which had taken place. There were also many fine terraces shown along this coast and their existence supports the other evidence.

The weather compelled us to run into a little cove near the point just off Dapitan. Of all the many inlets along the coasts of these islands I believe this to be one of the prettiest and most secure. No sign of an entrance can be seen at less than a kilometer away and certainly this point would be too obscure to pick up at night. We went through a channel not over 45 meters wide between walls which in the darkness I took to be limestone, and emerged into a splendid basin with water as clear and placid as a mountain lake and with high walls on nearly all sides.

By noon of the next day we anchored off the little stone fort at the entrance of Panguil Bay, which is in the extreme southwest corner of the much larger Bay of Iligan. The most conspicuous object at this place is Mount Malindang, an extinct volcano close to 2,700 meters in elevation lying to the west. Material from the slopes of this mountain is basaltic as I discovered by going up Panguil Bay in a *banca* in company with Lieutenant Lattamore, Philippines Constabulary, and a detachment of soldiers, landing at several points to enable me to go far enough inland to examine the rocks, as there are no outcrops on the coast.

Mount Malindang is an old crater the rim of which is broken down on the side toward Misamis. It is for the most part covered with a luxuriant mantle of timber forest; the soil on its slopes is of a rich red and is undoubtedly very fertile.

A number of Visayan colonies exist on the west side of Panguil Bay, but all the country to the east is Moro.

We left this point on the morning of November 11 and reached Camp Overton at a little after noon. Mr. Ickis was to join me at this point, but as he was detained by quarantine, Lieutenant Caffery and I went forward over the military road to Camp Keithley (745 meters) where the climate is much cooler than in the coast towns.

There is very little coastal plain in the region of Camp Overton, the hills rising so abruptly that the road has to wind back and forth in order to make the ascent. The first part passes through raised coral reefs, in which the species are for the most part identical with those growing in the sea below, but within about 300 meters the road cuts through basalt, and continues in this formation until Malabang on the southwest coast of this portion of the island is reached. Maria Christina Falls are situated but a short distance off the main road, a few kilometers out from Overton. Here the swift waters of the Agus River, which drains Lake Lanao, fall over a cliff 58 meters high and continue to the sea through a narrow gorge.

It has been estimated that sufficient power can be developed by these falls by means of turbines to run electric freight and passenger trains from Camp Overton to Camp Keithley and then around the lake and down to Malabang. Furthermore, the power from this and the Mataling Falls together should also be able to furnish electric light for a dozen towns and camps along this route.

The rock in the upper portion of the section at the waterfall is a hard, rather structureless basalt; below this comes a more or less loose volcanic conglomerate, or better, agglomerate, the geologic structure giving the most favorable conditions for fall formation. Maria Christina has about the same height and volume of water as the better known Majayjay Falls of Luzon.

The road, very soon after the fork to the waterfall, leaves the rather heavy timber. From here on it ascends a long, gradually sloping, quite open and rolling plain, resembling the western prairie of the United States.

The Agus flows in a broad valley with gently sloping sides at Numungan and while at this point it has a fairly rapid current, it gives no intimation whatever of the terrible plunge a few miles farther on. A party of engineers is stationed at Pantar some distance beyond this point to look after the roads and bridges, and we spent two days here to examine the cuts along the road and river bank. Basalt is still the country rock here, but it has on top an extraordinarily thick mantle of weathered material full of basalt bowlders, and both in constitution and topography this simulates glacial morainal material.

From Pantar the road runs fairly straight for seven to nine kilometers across open rolling country to the "Keithley escarpment." Beyond this escarpment lies Lake Lanao. The road continues almost due south to the foot of this great wall, then turns practically due east and, keeping nearly parallel with it, climbs gradually to the top. From here it runs down a long, easy grade to the margin of the lake.

This escarpment is very striking, and is made up from top to bottom, as far as can be seen from its cuts in the road, of loose material, unsorted and with apparently no definite structure, forming a wall 155 meters high. A simple explanation of this phenomenon is not easy to find.

To the left, when facing toward Camp Keithley from the top of the embankment, rises the dark, heavily wooded mass of "Sacred Mountain" some 300 meters higher. In the middle distance stands a prominent, grass-covered bump known as "Signal Hill" and beyond lies the lake and still farther back the dark, volcanic range of the Butig Mountains on the southeast. To the southwest the striking peaks known locally as "Ganasi" appear.

Usually, when the visitor first sees Lake Lanao, if he has any curiosity at all, he seeks the most natural explanation in a volcanic region, namely, that it is a crater lake. There may be some resemblance to a crater rim on the south shore near Camp Vicars, but in other places there is no trace of it. I first was favorably inclined to the belief that it was a valley dammed by glacial wash and I found no trouble in likening the Keithley Escarpment to a terminal moraine. I was forced to abandon this hypothesis for reasons which will be stated in a paper on the geology of this region which is to follow. My provisional conclusion with regard to Lake Lanao is that it occupies an old basin, partly tectonic, partly caused by erosion, between the mountains; this basin has been dammed by lava flows and other volcanic materials from the mountains adjacent to it. Subsequent weathering has given the aspect of a pseudo-glacial till to the material forming this obstruction. The explosion-crater theory has occurred to me and some attention will be paid to it in this connection in the later geologic discussion.

Camp Keithley is situated partly on the brow of the escarpment of the same name and partly on the slope to the lake. The small village of Marahui lies on the lake shore on the west bank of the Agus. Here is the residence of the district governor and here too, the tribal court is held. This village also has a native market, so that Marahui is the best place in the whole lake region to see the Moro people.

Mr. Ickis joined the party in Marahui and we crossed Lake Lanao in a *vinta* with a large sail and awning made of some species of palm. It was almost nightfall when we ran into a small cove and landed, and in the darkness we began the ascent of 155 meters up the high bluff on which Camp Vicars is situated. This distance is between 4 and 5 kilometers. Three days later we set out for the Taraca River on the east side of the lake with an escort of twenty scouts, sixteen cargadores, and several guides. The country around Vicars is open and rolling and very similar to that south of Lake Lanao. Very little of the land is under cultivation.

On the second day we finally descended from the high bluff we had been following and crossed an estuary, thus saving many miles of circuitous travel. The low flats which border this side of the lake extend back for several miles. The trail on the other side of this estuary lies through paddies and swampy areas. Every morning during our march was clear and bright, but the afternoons without an exception were rainy.

The region through which we passed contains numerous Moro forts or walled towns termed "*cottas*" peculiar to the Lanao Lake district and to Sulu. The walls are several feet in thickness, made of earth, and protected by a dense hedge of bamboo growing at the top. A moat nearly always surrounds the *cotta* and a drawbridge of bamboo is provided. Bamboos, into the closed joints of which have been placed long, slender-barreled brass cannon, known as *lantakas*, are thrust through holes in the walls. The *lantakas* are imported from Singapore. We passed fifty or more of these *cottas* in our trip around this part of the lake. Some of them shelter only one or two houses, whereas others contain a score or more dwellings, mosques and other edifices, in fact an entire village. Each *datu* or sultan lives in his *cotta* with his family and retainers close about him, and there is constant petty warfare among the various chiefs.

On the fourth day we reached the Taraca River and stopped at the house of a friendly *datu*. His *cotta* was, perhaps, the most elaborate we had seen; an elevation is shown by fig. 1.

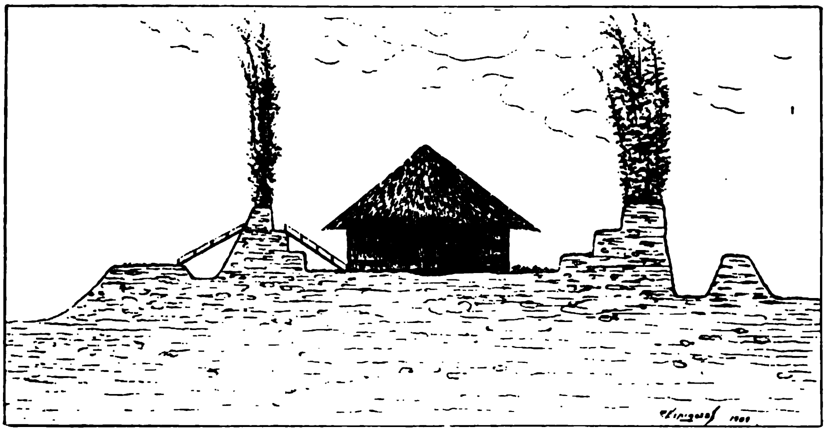

FIG. 1.

It was impracticable to ascend the Taraca River as far as the foothills to look for copper ore which had been reported from that point, because of the high water, the absence of trails along the bank, and the nature of the inhabitants. We did ascend for a distance of about 2 kilometers, but became almost hopelessly entangled in the ruins of old *cottas*, some recently destroyed by the Constabulary, others fallen into decay.

This condition caused us to continue our march to Camp Keithley and from here we again crossed the lake to Camp Vicars, from which point we set out for Malabang. The first portions of the road lie across an open, almost treeless country which affords a splendid view of the Buldung Range which runs in a long, high, serrated line eastward from Malabang, Some six or eight extinct craters of different heights, arranged so as to resemble steps, are visible in this range.

The road next enters heavy timber and at about one half the distance to Malabang, crosses the steel bridge over the Mataling River. The falls of Mataling are not so high as those of the Agus, but are scarcely less picturesque. The country rock is a basalt of more compact grain than at the other waterfall. The road runs into a very loose, black soil of sand and volcanic ash at a short distance beyond the bridge and continues in this formation to Malabang. This deposit of ash, at some distant date, issued from the now extinct Buldung craters. The most notable feature at Malabang is the line of cold springs issuing from the volcanic ash formation.

We next proceeded by trail from Malabang to Parang. Apparently all the country rock at Parang consists of basalt with well-developed columnar structure about 500 meters above the pumping station at the military post. Just south of the town the basalt sheet suddenly ends and sedimentaries, including coal measures, appear. Carbonaceous shales and certain fossiliferous beds indicative of coal deposits are here found, although no coal has as yet been opened up.

THE COTABATO REGION.

The country from Parang to Cotabato is rolling and but scantily timbered. The country rock consists of shales and soft sandstones dipping southward, that is, toward Cotabato. There are several small lakes in this region which are noteworthy, because of the great profusion of large, pink lotus and the abundance of ducks.

The difference between the topography in this region and that around Malabang is due to the absence of the lava capping which becomes thin just to the south of Parang. Whereas the streams in the lava country have a cross section like the following figure (fig. 2), those in the country to the southward beyond this sheet have more flaring sides to their valleys as is shown in fig. 3.

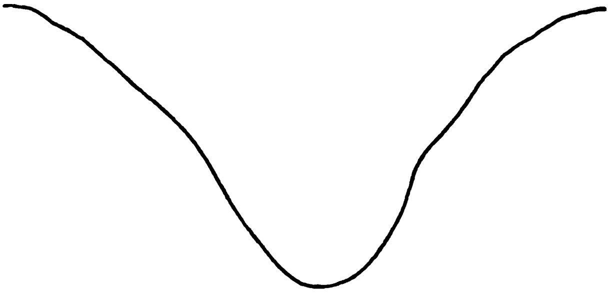

FIG. 2.

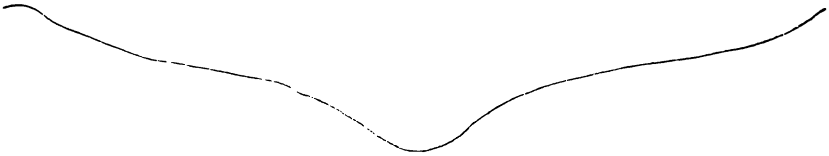

FIG. 3.

FROM COTABATO TO DAVAO.

The town of Cotabato is situated on the south bank of the north branch of the *Rio Grande de Mindanao.* It consists of a collection of low, white, Spanish houses fairly close together, with the usual native huts straggling about in the environs. Just south of and on the edge of the town is a limestone hill about 150 meters high from which a magnificent panorama (Plates XVI and XVII) can be obtained of the surrounding country. This hill is an outpost of a greater mass which is to be found to the south and which formerly was undoubtedly still more extensive; it is very remarkable in that it stands out in the middle of the great delta, which forms all the river plain from the mouth of the river back and even beyond Fort Pikit.

The most notable feature of the topography of this plain, beside the hill just mentioned, is the old terrace lines which swing along, but not always parallel to, either side of the river. These terraces are undoubtedly of marine origin, for close to Cotabato they are seen to be raised coral-reef shelves with the characteristic steep seaward slope of such formations. The evidence seems quite sufficient, to me at least, to suppose that the sea once swept far up this intermontane region which is now so filled with sediment. Indeed, I am convinced that it one time extended through to the Gulf of Davao, for in the stretch between the Pulangui River and Davao there are very recent sediments and volcanics which have closed up the passage.

Cotabato hill is composed of a cavernous limestone with a fair sprinkling of fossils, corals, gasteropods, lamellibranchs, etc., all of comparatively recent age, presumably Miocene, although no specific determinations have as yet been made.

Plate XVIII shows the interior of a native salt-making establishment at the lower end of the delta. Sea water is sprayed over glowing embers, the salt is precipitated and afterwards washed off and run through the large filter shown in the background of the picture. This filter contains wood ashes and earth. At the Moro foundry near Cotabato, bolos, krises, and many metal boxes of brass and silver are fashioned.

After some delay, we set out for *Datu* Piang's place at Cuderangan, some 50 kilometers above Cotabato. Here we learned from Lieutenant Younglof, Philippine Scouts, of oil seeping from the river bank about half way between Reina Regente and Fort Pikit and also near Pikit of a blue, plastic, oily clay which burns to a white color and is quite refractory. The Moros are said to come great distances to obtain this material.

Reina Regente is on a hill of limestone similar to that of Cotabato. It is a monadnock. The underlying foundation is sandstone which will doubtless be found to be a good water carrier; it is very probable that good conditions for artesian wells can be obtained at almost any point of the valley.

Fort Pikit, which dates from the Spanish régime, like Reina Regente, surmounts a limestone monadnock, but the latter is much higher than the one on which the former fort is situated. This is the farthest port on the Rio Grande.

From Fort Pikit we ascended to the end of navigation in the light-draft, stern-wheel steamboat which is used on the river. This point is some 50 kilometers beyond the fort, at the junction of the Kabacan with the Pulangui Rivers, the total ascent by steamboat being almost 200 kilometers.

The first three days of our march were through mud; we were continually forced to wade rivers, because we were following in the bed of the main stream, walking along the banks being out of the question, the first stop being at the junction of the Malabul and the Kabacan Rivers. We continued along the Malabul in a winding course, but making only 12 kilometers in a straight line in one day. A coarse, gritty sandstone and in places a typical conglomerate appear occasionally along the banks.

On the third day after we left Pikit, and six days' march from Davao, at an elevation of 365 meters, we reached the house of *Datu* Inkal, a Manobo chief. The geology in this region is not very prominent. The trail generally leads through dense underbrush. All the streams are filled with large bowlders of extrusive rock, evidently from the Matutan Range just ahead. The latter is represented on the Jesuit map as a long, continuous and rather formidable *Cordillera,* but it is nothing of the kind and, except for Mounts Apo and Matutan, it is merely a broken line of hills and quite low in several points.

The journey for the next few days can best be given by extracts from the diary.

December 16, 1907: Left *Datu* Inkal's at 7 a. m. Continued through jungle and over rolling country to an elevation of 580 meters where the trail goes through the pass. Halted and made camp beside a small stream. Rainy weather and leeches made traveling very disagreeable. The feet of the cargadores were bleeding freely, but they did not seem to mind it.

December 17, 1907: Broke camp at 7 a. m. Cloudy, elevation by barometer 472 meters. Crossed the Dalapnay River this morning. All the rocks for miles around this point appear to be similar, either fine-grained felsites, basalts and andesites or feldspar prophyries. Very little can be said geologically about this country at this time, as so little of it can really be seen. It apparently is extremely recent. Halted at noon at the Dalapnay River at a Manobo house and spent the afternoon of the 17th drying out our effects. Elevation at this point 412 meters.

December 18, 1907: All of this day we are going downhill through dry woods, for the most part consisting of small trees and little or no underbrush. Occasional basalt and andesitic bowlders are seen. The difference between this side (eastern) and the western side of the range is almost entirely due to the fact that the prevailing winds, moisture-laden from the Sulu Sea, give up their moisture on the western side of the mountains and the winds blowing off the Pacific lose much of theirs on the seaside of the mountains east of Davao. The appearance of these eastern-slope forests is not greatly unlike that of those in the Temperate Zone.

We halted for the night at 75 meters' elevation at Sinauilan Creek, where soft, brownish-gray sandstone and conglomerate is exposed.

December 19, 1907: Left camp at 6 a. m. Not much change either in topography or geology is apparent. Arrived at Digos, a small barrio on the coast of Davao Gulf, about 12 m., after a long walk over ground gently sloping to the beach. Here we spent the rest of the day and the night.

December 20, 1907: We sent our cargadores and guard on to Davao by trail while we took the launch *Bolinao* which stopped off this point at noon. We arrived at Davao about 7 p. m. after stopping at two or three plantations on the way and went ashore the morning of the 21st.

At Digos we obtained our first clear-cut view of Apo. The mountain stood out clearly and boldly, a sharp cone set to the south and back of an older truncated mass which had evidently blown off its head in some primordial paroxysm. On the southeastern side is a huge crevasse, from which puffs of a bluish-white vapor issue. Below 2,100 meters there is a dense jungle, a mass of green, but above this line the surface is all barren rock and apparently treeless, although when we ascended the mountain we found small bushes of blueberries.

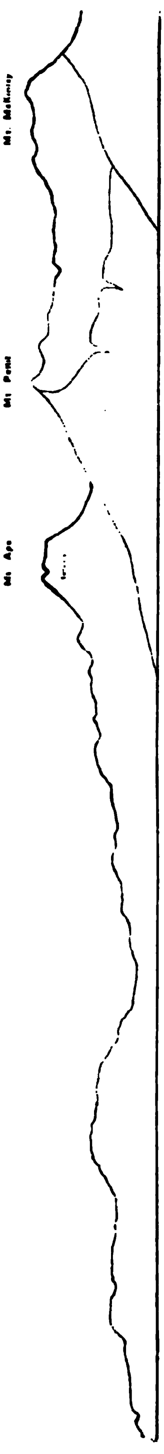

Fig. 4.

The present high peak known as Apo did not pour the great mass of lava and rock over this entire region. The explosion crater was about 8 kilometers to the northeast. Fig. 4 shows a profile sketch of this mountain.[19]

A walk back over the plain behind Davao is interesting. About 300 meters behind the town, or about 2 kilometers from the beach, unmistakable signs of old beach lines are found, marked by one distinct terrace at least 15 to 23 meters above the flat on which the town is located. All this territory is made up of alluvial wash from the hills. The bowlders are largely andesitic.

Lieutenant Caffery left the party at Davao to return to Zamboanga. Without his assistance the reconnaissance, up to the point where Davao was reached, would have been impossible.

Daron, on the west side of the Gulf of Davao, was the starting point for the ascent of Mount Apo, the party consisting of Mr. Ickis, Mr. Goodman, who had just arrived from Manila, and Messrs. Carrigan and

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[19] A good picture of Mount Apo will be found in the article on Volcanoes and Seismic Centers, in the Census of the Philippine Islands. (1903). 1, 201.

McCall, the last named having the kindness to furnish a launch to take us from Davao to Daron, and our thanks are extended to him for the courtesy.

We began the ascent of the first long, gradual slope toward Mount Apo on December 29. The trail first passes through hemp fields on the coastal plain and afterward it ascends gradually through a long, grassy slope which is strewn with occasional bowlders.

The first stopping place was at the house of Tankalin, the chief of the Bagobos. In appearance he and his people are very much like the Manobos. A short description of these people and one of their peculiar ceremonies has been given by me in a previous number of this JOURNAL.[2]

The remaining details of the ascent can best be given by extracts from the diary.

December 30: We are delayed because of lack of cargadores, the rear of our party not leaving until 10.30 a. m. We paused at 2.30 p. m. in the river bottom. Here some representative samples were collected from the bowlders in the agglomerate. These are largely angular and andesitic. The stream at this point is engorged in a steep-sided cañon, 300 meters deep. There are neither signs of ashes nor of lava in this cañon, although a great section is exposed. Everything points to there having been at some time a violent explosion, probably Krakatoan in magnitude. We pushed on to Pandaya, arriving 5.30 p. m. in a pouring rain and found one small, miserable hut.

The elevation of this place is 870 meters and in the early morning the temperature was 20°.5 C. During the night over half our carriers ran away, so we were left in a fairly precarious condition.

December 31: Messrs. Goodman and Ickis went ahead with part of the baggage; the remainder of the party remained to procure carriers, of whom we finally secured three, and to examine the rocks in the vicinity more carefully. There were five heavy packs, the lightest weighing 35 pounds. As Goodman and Ickis were also heavily loaded, all were compelled to assume the rôle of carriers.

The first, almost perpendicular rise of 180 meters was reached in a very short time, but the work was very trying to those who were unused to this kind of labor. The trail finally led along on a high ridge 300 meters above the water until nightfall.

January 1, 1908: About 10 a. m. some Bagobos came back on the trail as carriers, and soon after the camp of the advance party was reached. This place had been established by Major E. A. Mearns, Medical Corps, United States Army, who had been in this region collecting botanical and zoölogical material. The elevation as determined by the boiling-point method is 1,854 meters; the barometer reading giving 1,662 meters. This camp is situated on a little shoulder of the ridge in a fair growth of timber and close by is a small stream of cold water, containing both iron and sulphur salts in solution. The summit of the mountain can be seen from here through an opening in the trees and the fumes issuing from the huge crevasse on the eastern side are also plainly distinguishable. (See Plate XIX.)

January 2, 1908: The trail first leads upward through the heavy timber in the mossy forest belt, and then drops into a small creek bed which it follows up to 2,250 meters; here it passes beyond the timber line and through a growth of small blueberry bushes and stunted shrubs finally reaching exceedingly rough

[2] *This Journal, Sec. A* (1908), 3, 188.

ground; however, there are neither ashes nor lava. The pathway follows the south side of a huge crevasse visible from far below, and after following this for about 300 meters crosses to the north side and continues along it and around its head to a knife-edged ridge leading to the summit. This crevasse in some places is probably 20 meters deep and 250 wide, it has eight or ten vents from which vapors containing sulphur dioxide issue. A cone of fairly pure sulphur surrounds each vent; in individual cases these deposits may reach dimensions of several thousand kilos; possibly there may be 400 metric tons of this material altogether. It probably could not be handled conveniently.

A clay tablet with the inscription—

La única Expedición á Volcan Apó
1880
Montano y Rajal

exists at about 2,350 meters' altitude.

Our party reached the summit at a little after noon. So far as is now known, this is the highest mountain peak in the Philippine Archipelago. The altitude was determined by two trials with the boiling-point method, which gave respectively 2,956 and 2,902 meters. The barometric reading at the first trial showed 2,811 meters, which number is, of course, considerably in error. The old Spanish Coast and Geodetic chart of this region gives 3,143 meters, but work now being carried on by the Coast and Geodetic Survey of the United States shows that the Spanish work in these waters is in error.

The records of several parties are found on the summit, the earliest encountered being that of Schadenberg and Koch, 1882. None of the Montano expedition of 1880 was visible and possibly the tablet at about 2,600 meters' altitude has been carelessly or maliciously removed from the top where it was originally placed.

The highest point of the mountain, as determined by measurement, is reached by crossing a low sag to the next pinnacle, and here is placed a cairn containing a brass tube with a screw top marked "S. C." Inside is a neat scroll of the Sierra Club of California, duly stamped with its seal and signed by its president, John Miner. This scroll was deposited in the month of October of 1904, by Dr. E. B. Copeland, formerly of the Bureau of Science. Our party was the first to sign on the register.

Sights, with the transit, were taken at all prominent points of the topography and boiling-point determinations were also made, although the work was much hampered by fog. The weather cleared in the late afternoon and we were able to observe the panorama from the summit.

The Gulf of Davao was plainly visible with its island and coves, encircled by dark green wooded mountains and long volcanic slopes. The Rio Grande cuts across the foreground as a silver streak, extending far in the midst of many folds of green which continue without break to the skyline to the westward. The vast extent of the jungle in this island is very strongly impressed upon the observer. Mount Matutan is visible some 62 kilometers away, appearing as an isolated cone. It was sighted with a level, and appears to be but little lower, even at that distance, than the point on which we stood. If the curvature of the earth is taken into consideration, it is quite possible that Matutan will be found to be appreciably higher than Apo. No record, so far as I know, of an ascent of the former exists.

Mount Apo shows a circular depression suggestive of a crater at the top and, although the rock is igneous and gases issue from a great fissure in the side of the mountain, I would not, in the strictest sense, term it a volcano for the following reasons:

1. There are neither ashes nor signs of lava outpourings; the rock on this part of the mountain is rather more holocrystalline than effusives usually are.
2. The "crater," as it apparently shows no signs of the products of vulcanism about it, might be explained as a water erosion cirque; this question will be discussed more at length in the paper on the geology of Mindanao.
3. The structure of the mountain is schistose due to pressure and shows clearly that this is a structural peak. Plate XX shows this schistosity and its anticlinal course.

The morning temperature at the summit was 8° C. A small lake exists on a shoulder of the mountain, apparently about 500 meters below the summit; it was not visited. The return to Davao occupied two days. Here I left the expedition to return to Manila, and Messrs. Goodman and Ickis continued the reconnaissance from Davao to Surigao by way of the Agusan River.

ILLUSTRATIONS.

PLATE I. Map of Mindanao.
II. Map of the Sulu Archipelago.
III. Schists in the Tumaga River, Zamboanga.
IV. Sandstone slightly schistose in the Tumaga River, Zamboanga.
V. Volcanic agglomerate in the Tumaga River, Zamboanga.
VI. Subanuns.
VII. Beach and terrace just north of San Ramon, Zamboanga Peninsula.
VIII. *Datu* Lukas seated before his house.
IX. Flat-topped crater of an extinct volcano near Maibun trail.
X. View of Bud Dajo from the Maymbung trail.
XI. Palace of the Sultan of Sulu.
XII. A Moro village near Jolo.
XIII. Slopes of Suliman-tangis, Jolo, P. I.
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XVI. View toward Tomontaca (south), valley of the Rio Grande.
XVII. Panorama of the lower part of the valley of the Rio Grande.
XVIII. A native salt-making establishment on the lower Rio Grande.
XIX. Mearns' resthouse at 1,800 meters' altitude on Mount Apo.
XX. The summit of Mount Apo.
XXI. Showing cencentric weathering in igneous rock.
XXII. Map of route from Cotabato Valley to Davao Gulf.
XXIII. Map of route from Davao Gulf to Mount Apo.
FIG. 1. (In the text.) Elevation of a *cotta*.
2. (In the text.) Valley with steep sides.
3. (In the text.) Valley with flaring sides.
4. (In the text.) Profile of Mount Apo.

PLATE V.

PLATE VI.

PLATE VII.

PLATE VIII.

PLATE IX.

PLATE X.

PLATE XI.

PLATE XII.

PLATE XIII.

PLATE XIV.

PLATE XV.

PLATE XVI.

PLATE XIII.

PLATE XIV.

PLATE XVIII.

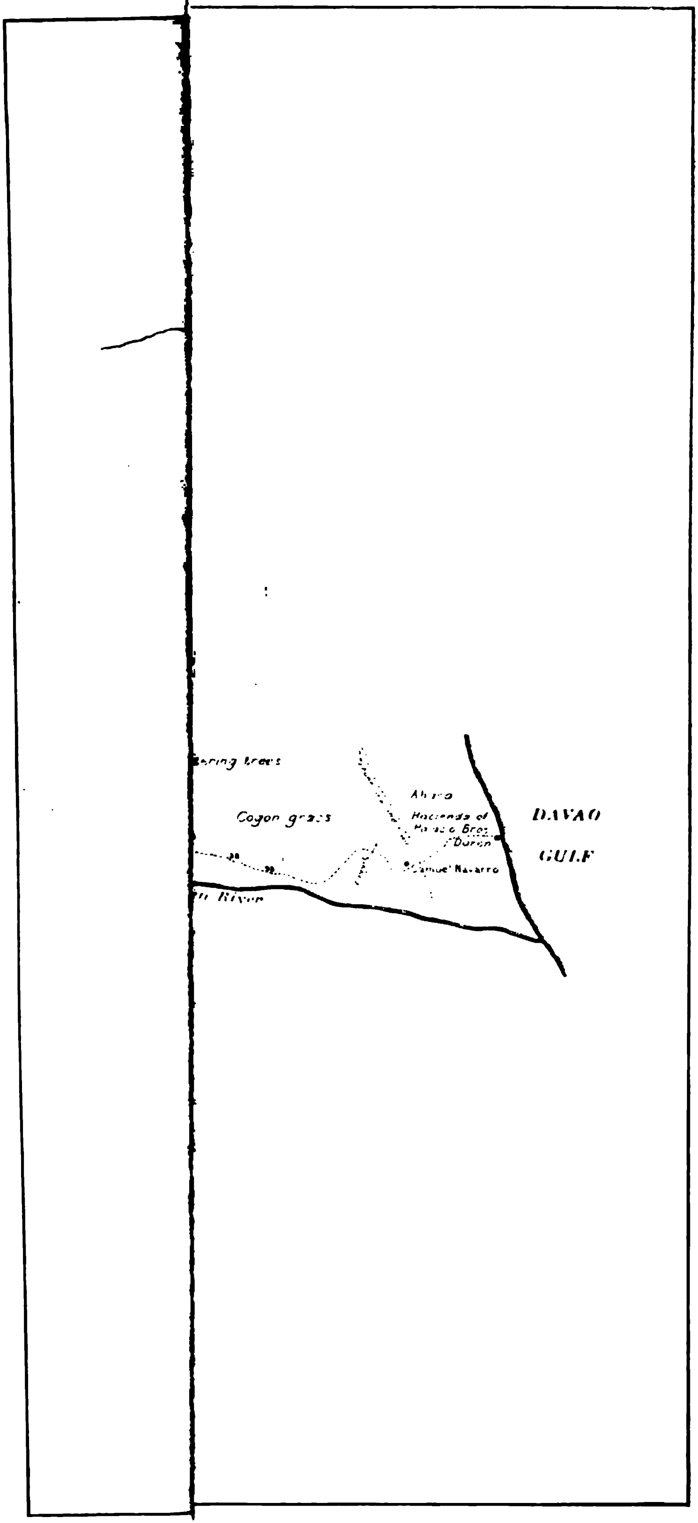
PLATE XIX.

PLATE XVIII.

PLATE XIX.

PLATE XX.

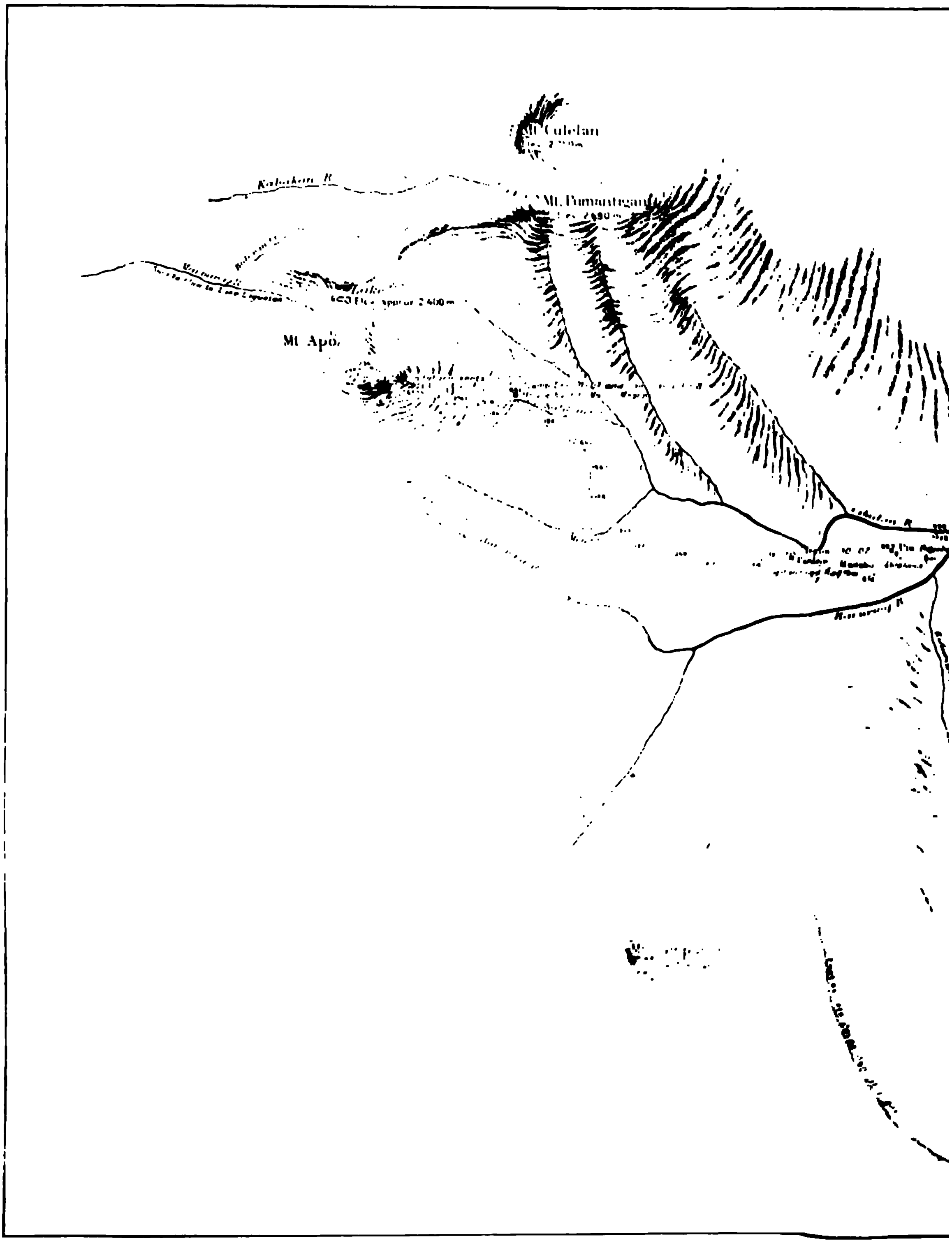
PLATE XXI.



DECEMBER 1907

SURVEYED BY PACING AND PRISMATIC COMPASS
ELEVATIONS BY ANEROID, CHECKED BY HYPSOMETER
FIELD WORK BY H. M. ICKIS AND M. GOODMAN
DRAWN BY H. M. ICKIS

P 4.



DECEMBER 1907

PLATE

A RECONNAISSANCE FROM DAVAO, MINDANAO, OVER THE DIVIDE OF THE SAHUG RIVER TO BUTUAN, INCLUDING A SURVEY FROM DAVAO TO MATI.—NARRATIVE OF THE EXPEDITION.

By Maurice Goodman.

(*From the Division of Mines, Bureau of Science, Manila, P. I.*)

INTRODUCTION.

Before beginning the reconnaissance from Davao to the Agusan River, I decided during a short absence of Mr. Ickis to make a journey from Davao to Mati, in order to collect geographical and geologic data on the traverse across the Pujada Peninsula. The overland route was taken both going and coming.

THE PUJADA PENINSULA.

The start was made on January 16 from Piso on the west coast of the Gulf of Davao, in a small *vinta* or sailboat, to the Moro village of Sumlug where three Moro guides and carriers were obtained; thence we went to Koabo, a deserted village with only a few dilapidated huts and a small number of coconut trees, farther south on the east coast of the gulf.

The coast line of this portion of Mindanao was at this time being surveyed by a party from the Coast and Geodetic Survey. Therefore, I confined my topographical sketching to the interior. The distance between the Gulf of Davao at Koabo and the town of Mati on Pujada Bay is approximately 21 kilometers, and between the two coasts the country is entirely uncultivated and uninhabited. The trail for the most part leads over a slightly hilly country, covered with a comparatively thin forest growth which, however, is sufficiently dense to make observations upon prominent points at any distance from the path almost impracticable. The ridge forming the backbone of the peninsula which terminates in Cape San Agustin, is rather low at this place, being less than 200 meters above sea level where the trail crosses the divide. The core of this ridge is of igneous origin and has undergone minor metamorphism. The original, unaltered diabase, which is the most common rock encountered, presents the typical ophitic structure and contains in addition to the feldspar and ferromagnesian minerals, a considerable proportion of secondary quartz and microscopic crystals of apatite.

A fractured, but hard and siliceous noncrystalline rock, which under the microscope plainly exhibits a flow structure, is also encountered. This is undoubtedly the surface phase of the igneous flow. Another phase of the basal rock is a chloritic schist, reddish-brown in megascopic specimens, and containing a large amount of secondary quartz. This rock is probably an alteration product of the original diabase.

Both coasts of the peninsula are composed of sedimentary strata. A pink limestone intersected by numerous veinlets of calcite rests on the west flank of the igneous intrusion, while the east coast is mainly conglomerate and brown shale. At Mount Badas these beds attain a thickness of ever 180 meters and dip about 45° toward the southwest.

East of Mati and between the Bays of Pujada and Mayo is a stretch of agricultural land about 13 kilometers in width. The greater portion of this consists of a table-land elevated about 30 meters above the general level of the present coastal plain. The plateau is terminated to the east and west by steep slopes; on the south, a narrow spit of land, which at high tide is but very little elevated above the sea, connects this table-land with what originally was undoubtedly an island off the main coast, but is now the southern point of the peninsula which separates Pujada Bay from Mayo Bay.

The country becomes more rugged and mountainous east of Mayo. The geologic formation is entirely sedimentary. The ridge extending from Mount Mayo to the bay of the same name, terminates in a bluff of conglomerate, dipping at an angle of approximately 30° to the east. At the coast line, the conglomerate presents a section of about 150 to 200 meters in thickness, and is composed of small, igneous bowlders. The wave action on this coast is extremely powerful, particularly during the period of the southwest monsoons, and the resulting erosion of the softer beds is plainly marked.

At a place called Lucatan, about midway between Mayo Bay and the town of Tarragona, the formation changes from conglomerate to limestone, the latter apparently overlying the former. The limestone is coralline in structure and is plainly an old reef rock that has been elevated to its present height by the general uplift of the coast. The dip and strike of this formation could not be ascertained, but as it is succeeded on the east by another outcrop of conglomerate, dipping about 14° in the direction S. 77° E., it must be inferred that the limestone lies unconformably on the underlying conglomerate, or else that the uplift was succeeded by a later stage of subsidence. For lack of supporting evidence of this latter theory, I am inclined to believe the existence of an unconformity the more probable.

An outcrop of a seam of coal about 85 centimeters thick exists on the south bank of Cabatoc Creek, about 9 kilometers north of the town of Tarragona. The seam dips at an angle of about 15° in the direction S. 50° E. A conglomerate or coarse sandstone immediately underlies it, while above lies a soft, brown shale, which in turn is overlaid by an impure limestone.

The coal shows traces of its original, woody structure, is separated by several clay partings, is lignitic in character and composition, and yields the following analysis as determined by the division of chemistry of the Bureau of Science:

	Per cent.
Water	11.47
Volatile combustible matter	23.87
Fixed carbon	14.08
Ash	50.58
Calorific value in calories	1,750

The sample submitted was obtained from the only observed exposure, and the low grade of the coal as shown by the analysis must therefore be partly charged to the long period of weathering which such a surface outcrop must naturally have undergone. However, at best, because of the thinness of this the only known outcrop, the clay partings which subdivide it and its long distance from any good port, the deposit must be considered of very doubtful commercial importance. Its chief value lies in indicating that conditions favorable to the formation of coal have existed in this region, and further prospecting may reveal more promising deposits.

After making this short reconnaissance, I returned to Davao, from which point the general plan was once more taken up by the reconnaissance to the Agusan River and down this stream.

DAVAO TO THE AGUSAN RIVER.

Mr. Ickis having joined me, we left Davao on January 31, having received as guide from the tribal-ward headman of Lasan the services of Comansing, his Moro chief of police. We traveled by launch for about six hours in a north-northeasterly direction to the mouth of the Tagum River, and up the latter about 10.5 kilometers to a small aggregation of huts known as Bincungan. The coast line as far as we could observe was thickly wooded, and only occasionally patches showed signs of cultivation. The inhabitants of Bincungan are for the greater part Manobos.

In passing through the Straits of Pakiputan, we encountered a fleet of seven pearling vessels actively employed upon an unusually rich bed of pearl shells deposited upon a narrow shelf on the west coast of Samal Island. We learned at a later time that the bank was stripped in about six weeks, and while valuable beds still remained they were at depths which the local divers with their apparatus considered unsafe.

The route was begun at Bincungan and carried up the Tagum and Sahug Rivers across the divide to the Agusan River, then down the latter to Talacogon.

Our facilities for this sort of work were extremely small. We had no means of obtaining with any degree of accuracy the speed and therefore, the distance traveled. We carried one pocket aneroid and one hypsometer. Unfortunately the former was accidently broken on the fourth day out, so that we had to estimate all altitudes, checking them when opportunity offered with the hypsometer and vertical angles taken with a Brunton Pocket Transit. However, I should say that considering the disadvantages under which we worked our combined estimates checked surprisingly well with whatever more or less reliable data we could obtain.

We carried a chronometer and transit for the purpose of determining the geographical position of various points on our route, but the rate of the chronometer and some other essential notes were irredeemably lost when Mr. Ickis was murdered, so that these checks are now impossible.

The Tagum River is navigable for launches from Bincungan as far as the barrio of Biaksabangan. The river narrows down from about 90 meters at the former place to approximately 60 at the latter, and its banks, which are about 3 meters above high-water level, are partly cultivated in hemp.

Biaksabangan is the junction point of the two main rivers, which go to form the Tagum. The western branch, the Libagano, rises on the south flank of the Panamboyan range and flows southeast towards Biaksabangan. Very little is known in regard to the valley of this river, but it is supposed to be entirely uncultivated and to be inhabited by Atas and other savage tribes.

We left the launch at Biaksabangan, and continued our journey up the Sahug River in a *banca*. This stream is about 30 meters wide at its mouth, and flows in a tortuous course through banks elevated about 5 meters above the water level. These consist of a brown and blue clay soil, overlying sandstone. The beds are practically horizontal with the exception of minor folds of very limited extent.

The people are long-haired Mandayas, and are engaged for the most part in the cultivation of small patches of hemp, for which their sandy clay soil seems to be well adapted.

The first stop on the Sahug was at the barrio of Kambanguy. Men to row us further up the stream were secured with great difficulty, and only after the headman of the village provided the party with men armed with spears and shields. The river is only about 15 meters wide at this place and continues to grow narrower up to the barrio of Kalilidan, about 4 kilometers up the stream. The banks rapidly become more thinly populated, and the cultivation grows proportionately thinner.

We observed dark, boggy, deposits, consisting largely of leaves, twigs, and branches at numerous places along the stream. These deposits were 0.6 to 1.3 meters thick, and some at least showed distinct planes of sedimentation. They were plainly of quite recent deposition, and further convinced us of the fact that this region is one of recent elevation.

We started from the barrio of Kalilidan on the fifth day of the journey with twelve men all armed with spears and two with shields. No Moros live along the Sahug River north of Kalilidan, and we met no one who could speak Spanish until we reached Veruela on the Agusan River, where some of the municipal officials talk that language.

The *bancas* were abandoned about 3 kilometers north of Kalilidan at a small barrio termed Mantinlad. The river widened from about 15 meters to approximately 30 between Kalilidan and Mantinlad, but it also shoaled very much, so that a short distance beyond Mantinlad, it became impossible to float a loaded *banca*. Several more deposits of black, semidecomposed and partially carbonized vegetable matter resembling peat were observed on the banks.

We traveled in a northeasterly direction from Mantinlad through a rather thick forest, climbing two hills about 75 meters high, and returning to the Sahug, where we cossed over to the right bank. The ground was too thickly covered with vegetation to permit of determining the underlying geologic formation, but to judge from its configuration, from occasional bowlders and from the character of the soil, it is presumably sedimentary and probably an argillaceous sandstone. In the bed of the Sahug River we picked up numerous bowlders of coralline limestone and calcareous conglomerate of apparently such recent origin as to bear out the theory that this part of Mindanao has been elevated above sea level in a comparatively recent period.

The boundary line between the Mandayas and the Manguanas is at approximately this point. The Manguanas differ but little from the Mandayas in personal appearance. Their dialect is not quite the same and their habitations are a departure from any we had previously observed. For the most part their villages consist of small groups of dwellings built on high posts, strongly braced to prevent swaying in high winds or earthquakes. Access to the house is gained by means of a long, round pole, about 12 or 15 centimeters in diameter, which passes through a hole in the floor 4.5 to 6 meters above the ground. This primitive sealing ladder is set at a very steep angle, and instead of rungs it has notches about 5 centimeters deep cut into the front of it. The floor space is about 3 by 7.5 meters, and the house is usually entirely open at the sides with the exception of about two or three widths of boards immediately above the floor. Although these people all possess long and highly ornamented spears and bolos, the bow and arrow is the more commonly used weapon.

The unusual elevation of their houses is commonly supposed to be for the purpose of sleeping out of reach of a spear. However, the floors which might be made of boards as readily as the sides are in all the houses we saw made of split bamboo. Whether or not this is the main purpose for elevating the houses, they serve well as watch towers to guard the *camote* and corn patches which usually surround them.

Our carriers deserted at this point, and when after great difficulty we had secured others, the journey was continued northward through a practically uninhabited country, for the most part along a thickly wooded ridge about 100 meters in elevation. Outcrops were very few and far between, but from pieces of float we determined the underlying formation to be a yellow limestone of coralline origin, ranging in hardness from a very soft, porous variety to one almost holocrystalline.

On February 7, the route continued in a northerly direction for a great portion of the distance in the bed of Budyan Creek, which is a branch of the Magum River. The latter is about 30 meters wide where we crossed; it flows in a southeasterly direction into the Sahug River.

During this entire day we encountered only outcrops of an impure, compact, and greenish appearing sandstone containing a small amount of calcite. These beds, which evidently underlie the limestone, strike in a general north and south direction, and dip at steep but varying angles to the westward.

The route changed more to the northeast on the following day, ascending a densely wooded ridge termed Mount Kinabuungan, which we estimated to be about 400 meters above sea level at the place where we crossed it. This was the highest elevation attained on the trip to the Agusan.

Mount Kinabuungan forms part of the range which extends from Mount Panamboyan in a northeasterly direction to the Agusan River. This range constitutes the northern boundary of the Sahug River watershed. The inclination of the sandstone beds swings through an angle of about 45° in direction, the dip changing from west to northwest and the strike becoming approximately parallel to the Kinabuungan mountain range.

An outcrop of fossiliferous clay was observed on the Mauntoc River, at an elevation of about 175 meters above sea level, overlying a conglomerate which in turn overlies the sandstone. The fossils were all of marine shells, apparently of very recent origin, and many of them had been so little disturbed and so well preserved that they still retain their original color and polish.

Travel was necessarily slow at this point owing to recent rains because of which the rivers were swollen, so the party was compelled to spend the night on the bank of the Manacum River.

The clay beds on the following day's march showed some signs of increased dynamic action. They became somewhat folded and cleavage planes developed, perpendicular to the bedding planes. We traveled almost due east until we again encountered the Sahug River which we crossed at the barrio of Banglasan. At this point the stream is about 15 meters wide, flowing between clay banks about 5 meters high. Banglasan, which is about 200 meters above sea level, is the largest barrio we entered since leaving the Tagum River.

One of the affluents of the Sahug called Tabunanan Creek was the line of march on the next morning almost to the barrio of Hoagusan, which was reached early in the day. This place is situated on the divide between the Sahug and Agusan Rivers, and according to our hypsometer is 240 meters above sea level. The beds between Banglasan and Hoagusan consist of the same sedimentaries which had previously been encountered.

but just after leaving Banglasan one or two small bowlders of a basic, igneous rock were seen. For lack of any positive evidence to the contrary it is supposed that these bowlders originated in the underlying conglomerate and had worked loose from the matrix on weathering and disintegration.

The descent from the divide to the Agusan River was made along the bed of Banglag Creek. This stream is only about half a meter wide near its source, but is fed by numerous branching streams, so that in the 7 kilometers of its course to the Agusan it grows to a stream about 6 meters in width and more than a meter in depth. The descent is fairly uniform in grade, and the sides of the gorge it has eroded are high and steep, as far as the valley of the Agusan.

The Banglag runs over a series of strata beginning with conglomerate and sandstone lying practically level near Hoagusan, then over fossiliferous clay beds striking N. 15° W. and dipping 35° northeast. These beds are in turn underlaid by shale striking N. 20° E. and dipping towards the southeast, and in the Agusan Valley by a coarse, calcareous sandstone, which strikes approximately N. 60° E. and dips about 25° to the southeast. This last sandstone contains large fragments of marine shells in a calcareous matrix.

No evidence of marked or recent earthquake disturbances were observed on the route followed by the party, probably because the subsequent heavy growth of underbrush has erased or hidden the scars and fissures that may have been caused thereby; however, the territory traversed is supposed to be a region of violent seismic activity. The Rev. M. Saderra Masó, S. J., in writing of the seismic center of the Agusan River states:[1]

> "This focus is possessed of great seismic activity, as is evidenced by the long series of earthquakes observed and carefully recorded by the Jesuit missionaries of that region since the year 1890. In June, 1891, a violent earthquake was the beginning of a long and fearful seismic period. This earthquake produced most serious destruction to the houses and ground; fortunately owing to the wildness of the country, there was little loss of life or of property. The falling banks of the river dammed it in many spots. Long and wide fissures were opened everywhere, especially on the hills separating the Agusan Valley from the Hijo and Sahug Rivers, which empty themselves into the Davao Gulf. The earthquake lasted several minutes, and during this time, says an eyewitness, the ground was moving as the troubled sea. During the following months, or during more than a year, the earth trembled with more or less force every day. In June 1892, there was a second violent disturbance, shaking the same region and renewing the havoc of the preceding year. These two earthquakes shook the Island of Mindanao nearly from end to end, and were fairly perceptible in the eastern Visayas.
>
> "Since these dates small shocks have been more frequent in this region than in any other part of Mindanao. Their cause is probably geomorphic rather than volcanic. There are unmistakable signs that the southern coast of Mindanao,

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[1] Volcanoes and Seismic Centers, in Census of the Philippine Islands (1903), 1, 204.

comprised between Cotabato and Panguiñn Point, the most southern one of the island, is at present undergoing subsidence, while, on the other hand, an upheaval seems to be going on in the northeastern and Pacific coast of the island. The southwestern part of the epicentral region, especially the hills or low ranges where the widest fissures were opened, may be considered as the junction between the eastern ranges of Mindanao, running from Surigao to the San Agustin Cape, and the central one, stretching from the Dinata and Sipaca Points in the north, to Panguiñn Point in the south. All the rocks in this range, through which run the Sahug and the Tubñan Rivers, are of madrepore and polypus of recent formation, alternating with clay beds and limestone strata."

MONCAYO TO BUTUAN ON THE AGUSAN RIVER.

The Agusan River, just below the town of Moncayo, was reached on the afternoon of February 10, the eleventh day after leaving Davao. The river at this place had an average width of 41 meters and was about 1.6 meters deep at the time of our visit. There was a surface current averaging 3.86 kilometers per hour, equivalent to a discharge of 64.5 cubic meters per second. Moncayo consists of perhaps forty houses and is inhabited by Ibabaos.

The map of the river which accompanies this report shows the town of Moncayo to be situated on the right or east bank of the Agusan River, about 134 kilometers south-southeast of Butuan. The actual distance to Butuan, as measured along the course of the river, is approximately 250 kilometers. Our bearings were obtained with a Brunton Pocket Transit, while the distances were gauged by time.

The party left Moncayo on the morning of February 13, floating downstream in a small boat. Fortunately we had the current of this long river in our favor, otherwise, particularly during the period of high waters in which we traveled, progress would have been extremely slow and laborious. The banks are nearly everywhere 3 to 10 meters high and as the valley of the Agusan is very wide and flat, observations could not be obtained on peaks or mountains.

San Rafael, a small barrio of the town of Jativa, was reached in the afternoon.

The people of San Rafael resemble closely the Ibabaos or Mandayas from farther up the river, but they call themselves Agunitanos, which is probably a local name, for we heard it nowhere else. They possess a corrugated iron-roofed church, the first we had seen since leaving Davao, but this as well as all the other buildings in the barrio is in a very dilapidated condition. The dwellings are constructed more like the typical Filipino hut, and in place of the high, open-walled houses with scaling poles leading up to them, such as are constructed everywhere between the Sahug and this place, all, with only one exception, had nipa walls and ordinary, short, bamboo ladders.

The banks of the river between Moncayo and San Rafael consist almost entirely of a clay shale lying practically horizontal. A bank of fossiliferous blue shale about 9 meters high exists at a place below the barrio of Tag[illegible], on the west side of the river. The fossils which are all of recent marine origin are extremely numerous and splendidly preserved.

A considerable amount of chalcedony, and igneous bowlders, mostly andesite, carrying secondary quartz and zeolites was observed at the junction of the Agusan and the Buoy Rivers. These rocks are brought down by the Buoy River from the mountain range which separates the drainage areas of the Agusan River and the Pacific Ocean. We panned some gravel from near the mouth of the Buoy, but could find no colors.

We left San Rafael early the following morning, floating downstream with the current and arriving at the municipality of Veruela at 7 o'clock at night. The river was straighter and the banks somewhat higher and more timbered. The Agusan is wide and deep at this part of its course, and affords a splendid avenue for transportation, but the country is so thinly populated that very few *bancas* were encountered.

In spite of the fact that this region is one of the most marked centers of frequent and intense seismic disturbances, the beds of soft clay and shale which we found outcropping on the river banks lie practically horizontal and show no effects of dynamic action. An estuary leading into a small pond which drains into the Agusan is situated at a place called Maasin, about 3 kilometers south of Veruela. An outcrop of soft, blue shale, containing a large variety of fossil shells in an excellent state of preservation occurs on the west bank of this estuary. These fossils, as well as those collected at Tagusap and other places, have been sent to Dr. Smith at Leiden, Holland, for study and comparison.

Veruela was the first so-called Christian town that we entered after leaving Davao, and it is the largest on the upper Agusan. I should judge its population to be about 5,000, nearly equally divided between Christian Visayans and *conquistas* or Mandayan converts. The principal pursuit of the inhabitants is the cultivation of abacá and rice.

The river at Veruela is considerably wider and deeper than at Moncayo, but not as swift. According to our rough measurements it is 61 meters wide, about 2.3 meters deep, and has a surface velocity of approximately 2.17 kilometers per hour. These figures correspond to a discharge of about 95.5 cubic meters per second as against 64.5 near Moncayo.

The banks of the river about a kilometer below Veruela gradually become lower, until they disappear entirely; the main channel is choked with vegetation and the current is very much reduced. In place of the splendid river, there is a swampy jungle with alternating, swift, tortuous, and narrow channels and again wider stretches of almost calm water. This portion is termed Lake Linao and is a part of the Agusan River system. The lake is probably formed by a local depression of the surface, attendant upon a movement of the earth's crust. There are several lakes in this basin, but their boundaries are not well defined and a channel connects all.

Clavijo was reached in the afternoon. This town consists of one church with corrugated iron roof, and five dilapidated nipa huts, all but two of which were abandoned at the time of our visit.

The course of the next day's travel was very much the same as the preceding. A submerged basin was traversed which appears to be about equally divided between low, swampy ground and lakes, the latter being connected one with another by narrow and crooked channels which intersect the swamp in all directions. The main stream of the Agusan River was reached about noon. At this point it is about 65 to 95 meters wide. The banks are very low, and in places, during high water, only the tops of the high grass indicate their position. This region is entirely uninhabited. We arrived at Martires after nine in the evening, and during the entire day did not meet a single individual nor pass a single habitation.

Martires is a fair-sized town inhabited largely by *conquistas*, whose chief occupation is the cultivation of abacá. It is but an hour's travel from Talacogon, and so we arrived at the latter municipality early in the morning of February 18.

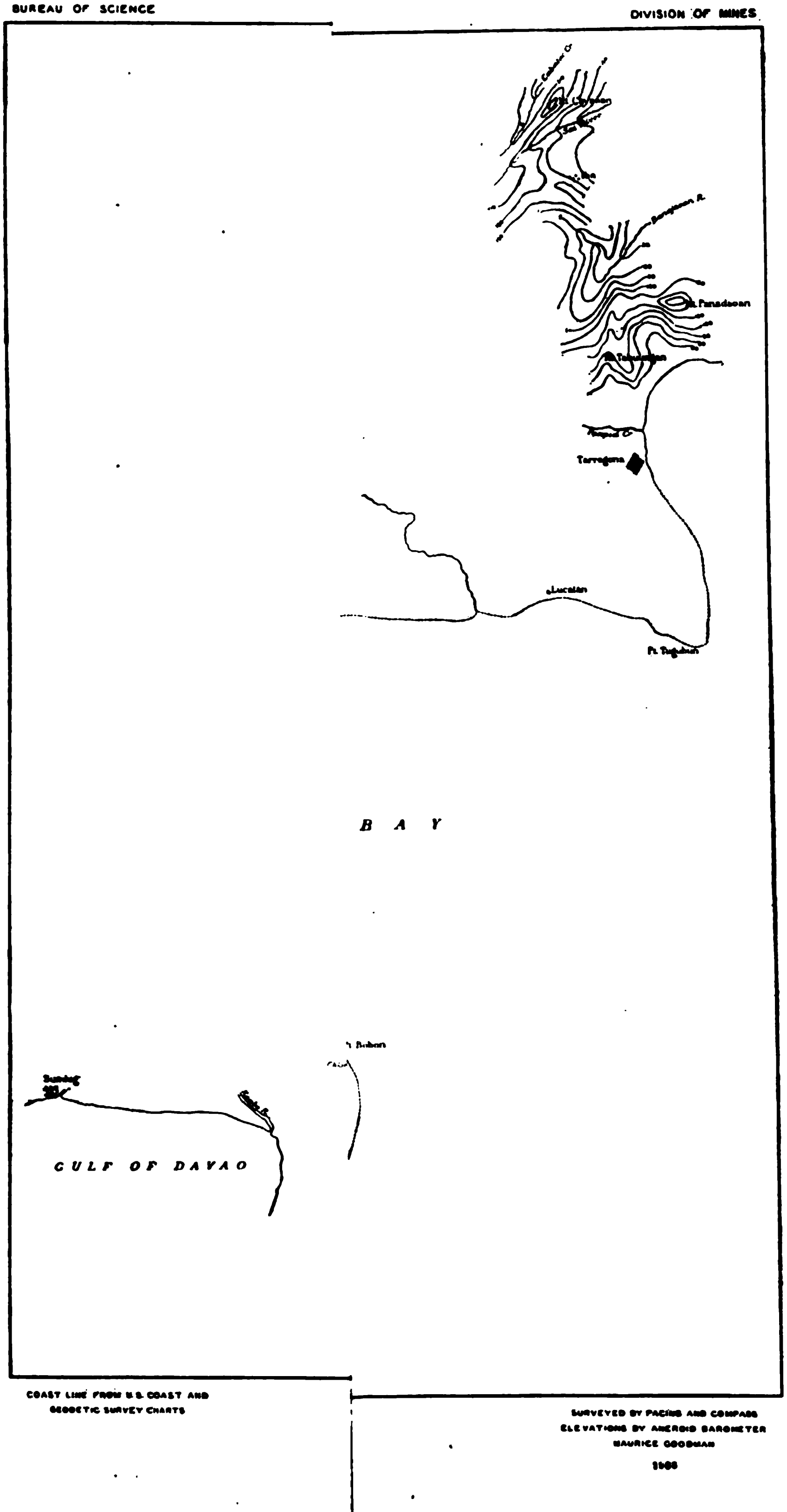
According to a previously arranged plan Mr. Ickis and I separated at this point, Mr. Ickis intending to go with Governor Johnson westward to Bukidnon subprovince, and I to continue northward to the mouth of the Agusan River, and then through the Surigao Peninsula to Placer and Cansuran to investigate the reported gold occurrences at those places. We both left Talacogon on the morning of February 21, I following the river towards its mouth.

An outcrop of argillaceous sandstone, highly fossiliferous, occurs at the junction of the Maasan River with the Agusan. Close approach to the outcrop is very difficult because of the force of the current at this point, but nevertheless a good collection of fossils was made. The bedding was observed to be nearly level, but the dip and strike could not be measured.

Butuan, the capital of Agusan Province, was reached on the afternoon of the following day. Near Butuan the river becomes quite wide. No measurements were taken, but at this point I estimated the velocity of the stream to be about 6 kilometers per hour and the width about 140 meters. The banks, which are very largely cultivated in hemp, consist for the most part of shales lying practically horizontal.

ILLUSTRATIONS.

PLATE I. Route Map—Sumlug-Mati and Tarragona-Mt. Cayaoan.
II. Map of route from Gulf of Davao to Butuan.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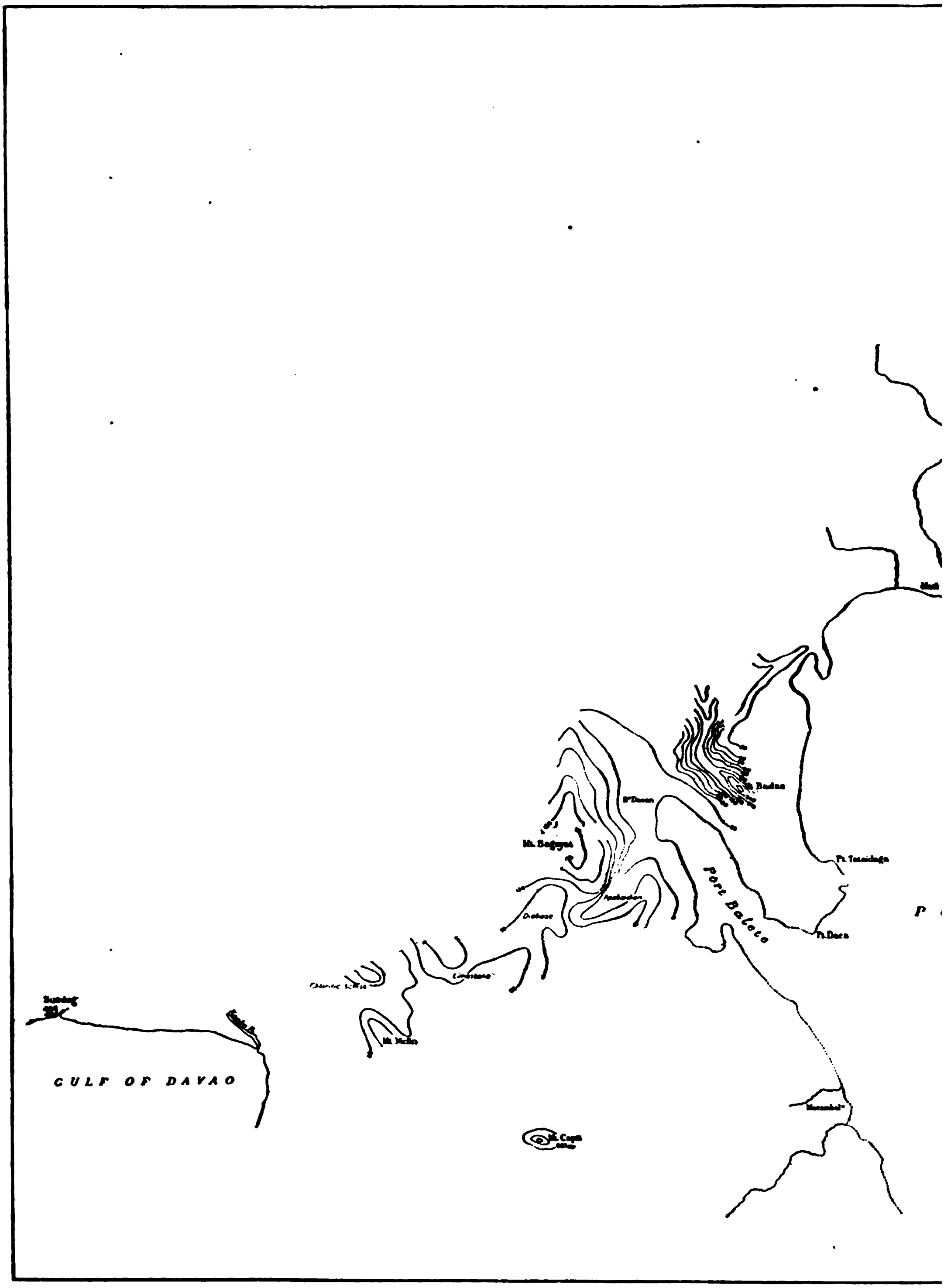
GULF OF DAVAO
COAST LINE FROM U.S. COAST AND GEODETIC SURVEY CHARTS
SURVEYED BY PACING AND COMPASS
ELEVATIONS BY ANEROID BAROMETER
MAURICE GOODMAN
1908

SUMLUG-MATI A

BUREAU OF SCIENCE



COAST LINE FROM U.S. COAST AND GEODETIC SURVEY CHARTS

ROUTE MAP.

GULF OF DAVAO TO BUTUAN BAY

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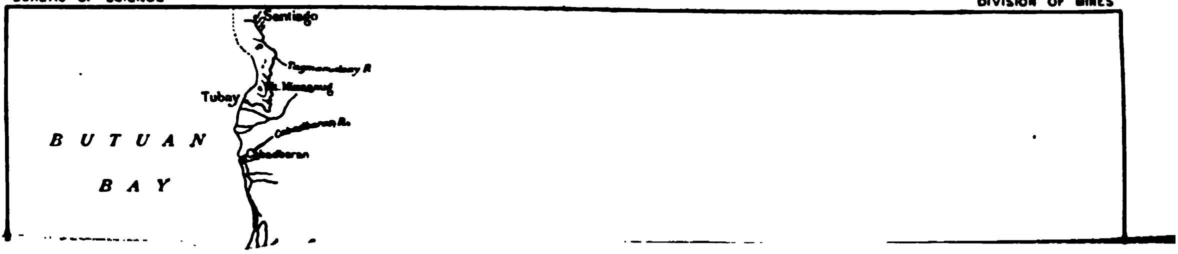

ROUTE MAP.

GULF OF DAVAO TO BUTUAN BAY

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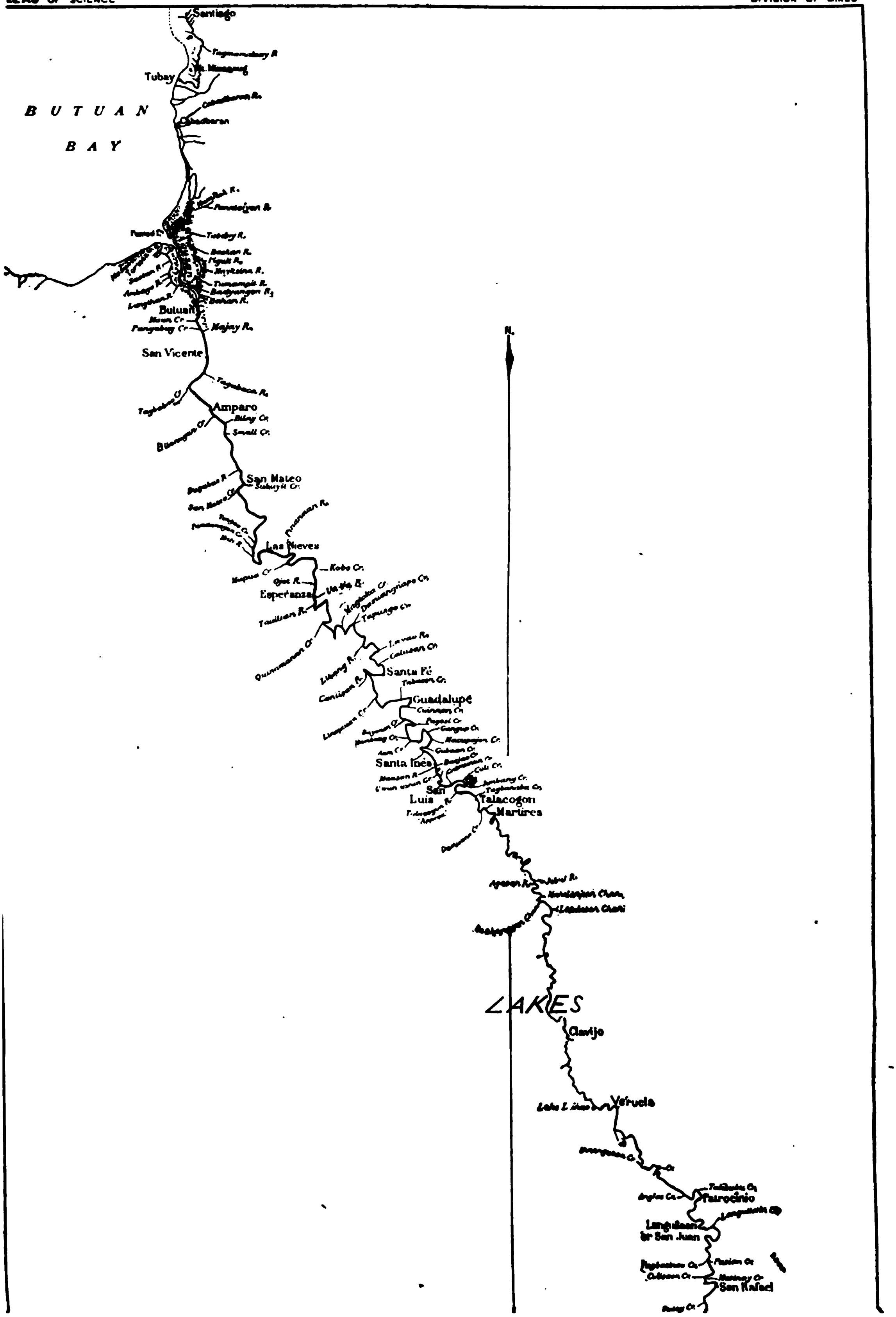

THE FISHERY RESOURCES OF THE PHILIPPINE ISLANDS. PART I, COMMERCIAL FISHES.

By ALVIN SEALE.
(*From the Bureau of Science, Manila, P. I.*)

INTRODUCTION.

We have received numerous requests for information regarding the commercial fisheries of the Philippine Islands, especially relating to the different kinds of edible fish and their abundance; the location of fishing banks and the methods of capture. We have also been asked if fishing, entered into as a commercial venture, would be profitable.

It is for the purpose of answering some of these questions that Part I of this series, based on my personal observation in the various islands of the group during the past year and a half, has been prepared. It is hoped that this paper, together with others to follow—namely, Part II, Sponge Fisheries; Part III, Pearl Fisheries; Part IV, Other Marine Products (aside from fishes, pearl oysters, and sponges)—will serve to create an interest and help in the development of the rich fishery assets of the Islands.

THE ANCHOVIES.

Family *Engraulidæ*. (Pl. I.)

There are at least four different species of anchovies in the Philippine waters, the most abundant, perhaps, being *Anchovia commersoniana* (Lacépède), called *dilis* in Tagalog, *monamon* in Ilokano, and *anakbat* in Moro. *Anchovia dussumieri* Bleeker, termed *dumpilas* in Tagalog, and *teggui* in Moro is a large species, but less abundant than the *dilis*.

The common anchovy (*dilis*) is found in great numbers along the shores of almost all the islands of the group; it is almost transparent, with very thin, deciduous scales. This species is a delicate little fish of fine flavor and would bring a good price, if put up in attractive form either in oil or spice, or if made into anchovy paste.

THE HERRINGS.

Family *Clupeidæ*. (Pl. II.)

There are about thirteen distinct species of herring represented in the Philippine waters and notwithstanding their rather small size, they are of considerable commercial importance. They abound in immense numbers along the coasts of almost all the islands of the group. Some are more or less migratory, others seem to remain near one place. Large numbers are caught in Manila Bay at all seasons of the year. These represent the forms called *tunsoy* [*Harengula moluccensis* (Bleeker)], *tamban* (*H. longiceps* Bleeker), and *bilis* [*H. gibbosa* (Bleeker)]. The young of all species are termed *siliñasi*. Great numbers are caught in corrals, especially during May and June; they are also taken in the drag-seine. It is not an unusual sight to see large *bancas* loaded to the gunwale with herring being landed at Tondo beach, where the fish are sold to the Chinese to be smoked and dried. The natives in Zamboanga buy large quantities to eat in the fresh state. Any of these sardines would compare favorably with the species put up in oil on the Pacific coast.

During the nine months from January first to September first, 1907, 85,000 pesos worth of canned sardines were imported into the Philippines; this, too, with the Philippine waters swarming with sardines and with an abundance of good sesame oil which could be used for canning purposes, produced in Manila.

THE SILVERSIDES.

Family *Atherinidæ*. (Pl. III.)

The silverside, called *guno* in Tagalog and Moro, and *ti-i* in Ilokano, is without doubt the most abundant fish in the Philippines. It is almost impossible to land at any wharf or go ashore on any beach without seeing these little fish in countless numbers. They usually grow to a length of from 10 to 12 centimeters. They have a greenish tint on the back and a bright, silvery band on the sides. There are five or six different species, but they appear so much alike that the natives have not distinguished between them, calling all simply *guno*. The most common species is possibly *Atherina temmincki* (Bleeker).

The *guno* are known as *pescados del rey*, "fishes of the king," among the Spaniards. They are greatly valued as food. The young are termed whitebait. The method of catching is usually by seine or corral. A profitable industry could be built up by preparing these fish in a good sauce, by packing them with spices, or by drying. An abundant supply for canning operations could be secured at any of the following places: Manila, Jolo, Zamboanga, Sitanki, Puerto Princesa, and perhaps a dozen other places not yet examined. They abound at all seasons.

THE MACKERELS.

Family *Scombridæ*. (Pl. IV.)

There are at least eight different species of the mackerel family found in the Philippines, all of them good food fishes and of commercial importance. In this family is the *tanguingue,* also called *tangili* or *tangi* (Moro), which is a true Spanish mackerel (*Scomberomorus commersoni* Lacépède). By many people this is regarded as the finest food fish in the Philippine waters. This fish is fairly abundant, and can usually be found in the markets, where it sells from 1 to 4 pesos, Philippine currency (50 cents to 2 dollars United States currency) per fish. At Zamboanga it is nothing unusual to see ten or a dozen of these fish in the market at one time, all of them measuring 90 centimeters or more in length. They are frequently cut up and sold by slices. The major part of the *tanguingue* are caught off shore with a hook and line, a good fishing ground being located off the east coast of Basilan. At Manila they are usually caught in nets. Another Spanish mackerel taken in these waters is *Scomberomorus konam* (Bleeker), which is scarcely distinguishable from the above.

Other important members of the family are the chub mackerels (*alumahan* or *carallas*), *Scomber microlepidotus* Rüppell, and the *hasa-hasa* (*Scomber japonicus* Houttuyn). These fish run in great shoals throughout the Islands, following small fish, upon which they feed. They enter Manila Bay in March and the inhabitants along the shore-line of the bay are kept awake during the nights by the noisy clatter of the fishermen beating with their paddles against the sides of their boats in order to frighten these much desired fish into the nets or hastily constructed corrals.

Still other members of this family represented in these waters are the small bonitoes (*sobad* or *tulingan*) *Gymnosarda pelamis* (Linn.), the great tunnies (also called *sobad*), and the albacore (*Germo alalunga* Bleeker).

All of these fish may be caught with hook and line, in nets or corrals. They are so abundant that it is unusual to make a trip among the Islands without sighting one or more shoals of fish belonging to this family. They are especially common about the Cuyo group and along the shores of Palawan. The market at Zamboanga is usually well stocked with all members of the family. They are with few exceptions fishes of the deep water. The purse-seine in my opinion could be profitably employed in their capture.

THE MUD FISHES.

Family *Ophiocephalidæ*. (Pl. V.)

The mud fishes, *dalag* (*dalak* in Moro), are of considerable importance, especially in the vicinity of Manila where they form a large part of the food of the native population. They are usually sold alive in the markets. In fact, it is their ability to stay alive out of water that attracts attention to them. They are primarily a fresh- or brackish-water fish, and after a rain almost all the little pools by the wayside, as well as the paddies and rivers are well filled with *dalag*. They have the habit of burying themselves in the mud as the ponds dry up and thus of lying dormant until the next rain. They take the hook freely, and it is no uncommon sight to see the natives fishing for them in the rice-fields, or in the most unlikely and recently formed pools. They frequently travel overland in the wet grass and can live for hours out of water. The eggs are deposited in holes in the bank; the mother exercises a care over the young fish.

In India these are regarded as one of the most wholesome fishes and are given to invalids. In Manila they are looked upon more as scavengers and are not much eaten by the Americans. These mud fish are distinctly carnivorous, feeding on small fish, refuse, etc. They are well distributed over the Islands, being found in almost all the lakes and rivers.

THE SNAPPERS.

Family *Lutianidæ*. (Pl. VI.)

There are about twenty different species of this family in the Philippine waters, all of them important as food fishes. They range when full grown from 25 to 90 centimeters in length. They are distributed over the entire group, some running up rivers to the interior lakes to feed. Several of the species are bright red in color and are called red snappers, one of the most abundant being the *bacbaan* [*Lutianus dodecacanthus* (Bleeker)]. Another snapper called the *camangbuhu* (*Lutianus fuscescens* Cuv. et Val.) can usually be found in the markets, especially in Zamboanga. A very important member of the family is the *alcis* (*katumbang* in Moro) (*Lutianus gembra* Bloch et Schn.). These are caught in great numbers in the Naujan River at Batos, Mindoro. The adults weigh from 8 to 20 pounds each. I saw 108 of these fish caught in one-half day at the Batos corral.

The best banks for red snapper fishing seem to be in the vicinity of Zamboanga. *Dapa* and *managat* are other Moro names applied to the red snapper. They are usually caught by hook and line, or in the corral. In Zamboanga a red snapper 35 centimeters long can be bought for 10 centavos.

THE POMPANOS.

Family *Carangidæ*. (Pl. VII.)

There are thirty-six different species of the pompano family known in the Philippines. All of them are valuable commercial fishes. The cavallas (*Caranx*) are the most important branch of the family. They are termed *talakitok* in Tagalog and *daingputi* in Moro. These fish are very abundant in almost all markets. They range from 32 to 36 centimeters in length. As a rule they are caught in corrals.

Another abundant species is the *lison* [*Caranx ignobilis* (Forskål)]. These fish are dried in large numbers by the Moros. The *ballangoan*, termed *cubal-cubal* (*Megalaspis cordyla* Linn.), is another very abundant food fish of fine flavor, belonging to this family. These are reported to reach the length of 155 centimeters; ordinarily those in the market measure about 45 centimeters. They are caught in corrals.

THE SEA BASSES.

Family *Serranidæ*. (Pl. VIII.)

There are thirty-three species of this important family of food fish reported from the Philippines. One of the most familiar is the *apahap* (*tapog* in Moro) [*Lates calcarifer* (Bloch)], one of our largest sea basses. Specimens weighing from 25 to 35 kilos are frequently brought into the market. This fish would afford good sport for local anglers. The largest branch of the family is constituted by the groupers (*Epinephelus*), called *lapo-lapo* in Tagalog, *garopa* in Visayan, and *kukkut* in Moro. (Pl. VIII.) Ordinarily this name is given to the most common species, *Epinephelus merra* Bloch, but it is also applied to at least three others which closely resemble *E. merra*. These fish bring a high price in the Manila market; they are a favorite sea food for many Americans.

Another rather common species is the blue-spotted grouper [*Cephalopholis stigmatopomus* (Richardson)], which is especially abundant in the Zamboanga market. The fishes of this family are usually caught with hook and line in water of considerable depth; sometimes they are taken by net or corral. Gill-nets set in about 50 feet of water frequently make good catches.

THE MULLETS.

Family *Mugilidæ*. (Pl. IX.)

There are ten different species of mullet recorded from the Philippines, the most abundant being the *banak* (*Mugil cephalus* Linn.). This fish can always be found in the market and when quite fresh and properly cooked is most delicious. It is very common throughout the entire Archipelago. The mullet is a strictly vegetable feeder, and is usually found wherever there is an abundance of sea moss. The shallow sea about the Island of Sitanki is a famous feeding ground for this fish.

On the morning of June 29 of this year I witnessed a most astonishing movement of mullet near the Island of Sitanki, Sulu Archipelago. A noise like a great waterfall was heard. Hastening to the beach I saw a vast shoal of the fish coming from the north, keeping quite near the shore; they were leaping along the water in great, flashing waves. The shoal was fully 100 yards wide and 500 yards long; there must have been over a million individuals in it. The fish seemed to be of almost uniform size, about 40 centimeters in length. Nothing stopped them. The natives jumped into the water and killed hundreds with sticks and stones; some were driven ashore, but the shoal passed, leaping, on to the south.

These fish were probably seeking a new feeding ground. They were not breeding, this fact being indicated by the extreme smallness of the ovaries. I should estimate that there were over one hundred thousand pesos' worth of fish in this one lot.

Several species of this family run up the fresh water rivers to the lakes. As many as ten thousand have been caught at one time with a drag-seine near the mouth of the Naujan River in Mindoro. These fish are easily dried and are a good commercial asset.

OTHER COMMERCIAL FISHES.

There are many other fishes in the Islands that are of commercial importance, but lack of space and time will not permit of a detailed description. However, among these we should mention the barracuda, called *pangaloan* or *lambanak* in Moro. This is an abundant and excellent food fish sometimes reaching the length of 1.5 meters. There are also numerous species of porgies, termed *bitilla, cutcut*, and *guntul* by the natives. These fish are especially abundant about Sitanki, and there they are dried in large numbers. Many members of the grunt family (*Hæmulidæ*) are also seen, these are termed *leffe*, *pasinco*, *bakuku*, and *bagong*;[1] they are especially valuable for salting and drying.

Several members of the gar family (*Belonidæ*), the croakers (*Sciaenidæ*), the parrot-fishes (*Scaridæ*), the surmullets (*Mullidæ*), the mogarras (*Gerridæ*) and the soldier-fishes (*Holocentridæ*) occur. All of these are good food fishes and of commercial importance. A provisional, but incomplete list of the Philippine market-fishes, giving the native, scientific, and English names will be found at the end of this article.

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[1] *Bagong* is a general term applied to any small fish mixed with salt and partly dried. Bagong is most commonly eaten in the interior where fresh fish can not be obtained.

THE MILKFISHES.

Family *Chanidæ*. (Pl. X.)

The *awa* or milkfish [*Chanos chanos* (Forskål)], called *bañgos, bañgod, kawag-kawag,* and *lumulocso* by the Filipinos and *bangellus* by the Moros, is one of the most important commercial fishes in the Islands. It ranges over the entire group, from northern Luzon to Sitanki and is the most abundant fish in the Manila market. Frequently, during protracted rough weather it is the only variety obtainable. It is raised chiefly in the fish ponds at Malabon and at other places near Manila and therefore can be secured at any time regardless of the weather.

This fish is particularly adapted to pond culture, being a vegetable feeder of rapid growth. The *bañgos* superficially resembles the mullet, but can easily be distinguished by the fact that the mullet has two fins on the back, while the *bañgos* has but one. The *bañgos* frequently reaches a length of 1.2 meters and then it is termed *lumulocso*. The eggs are deposited in the sea. The young appear during the months of April, May, June, and July and are called *kawag-kawag*. They are supplied with a yolk-sack which furnishes them with food until they are about 14 millimeters in length. At this age they are to be found in great numbers along the beaches of Zambales, Batangas, Mindoro, Marinduque, and doubtless in numerous other places. Here they are captured by the natives and placed in large earthen jars full of water called *palyok*. They are then conveyed to the fish ponds, frequently a hundred miles distant. (Fig. 1.)

One of the jars, *palyok*, contains about 2,500 young *bañgos*. They sell for from 20 to 25 pesos per *isang laesa* (10,000); about six *laesa* (60,000) are used to stock one pond of 1 hektare. As the fish grow they are thinned out by transfer to other ponds. Thirty-three per cent should reach marketable size. Four months after the transfer the *bañgos* should each be 25 centimeters in length. This size of fish retails for 9 centavos each; in 8 months the young are each 40 centimeters long and bring 20 centavos, while a yearling should measure half a meter and bring from 50 to 60 centavos.

FISH PONDS.[2]

Almost any kind of ground other than a sandy soil will do for a fish pond. It should be near salt water and not beyond the influence of the tide, as the *bañgos* thrive best in brackish water. A complete system should have at least four ponds. These should be so constructed that one equals in area at least that of the other three combined.

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[2] I am indebted to Mr. W. D. Carpenter of Malabon for most of the information regarding fish ponds.

Usually the area of the large pond is much greater. The dikes of the small ponds are low, often not 30 centimeters above the water level. These smaller ponds are of about equal size, being usually rectangular and each of about 200 square meters in area. The *palaistaan* are formed by throwing up dikes. The main dikes are large, especially along the banks of the so-called "river" or estero, where mangrove trees frequently are planted for their protection. The water from the estuary is permitted, when the tide is flowing, to enter one of the smaller ponds through a sluice (*pirinza*) usually constructed of masonry with two gates, one of several slides of solid wood for controlling the water and the other of close bamboo palings to prevent the egress of the *bañgos* and the ingress of undesirable tenants such as carnivorous fishes and crabs which burrow into the dikes and cause leakage. Snakes and birds are also evils that have constantly to be guarded against.

This small pond distributes the water supply to the others and is used for capturing the marketable *bañgos*. It is usually separated from the larger pond by a close paling of bamboo around the narrow opening in the partition dike. When it is desired to capture the fish in the largest pond, the paling is removed and a strong current is caused to flow from the smaller pond to the larger. The *bañgos* attracted by the fresh water swim against the current and enter the smaller pond in great numbers, where they are readily captured in a seine. This operation is often accomplished about midnight, so that the fish will be exposed in the Manila markets in the best condition.

The remaining two ponds, or subdivisions of the pond area inclosed within the limits of the boundary dikes, are connected with each other and with the pond which feeds the water by single pipes made of the hollow log of the *luyong* (*Diospyrus nigra* Retz). These tubes are called *palabunbuñgan*, the water and fish being controlled at these openings by a solid wooden plug or a funnel of bamboo strips. The water in these two small ponds is kept at a depth of but a few decimeters, the ponds being used interchangeably for cultivating the food alga (*Oedogonium*) and for developing the *kawagkawag*. (Fig 2.)

FOOD OF THE BAÑGOS.

If it is desired to cultivate the food alga (the large pond is originally stocked in the same way), the water is allowed to drain off and the clay is exposed to the full power of the sun. The alga rapidly makes its appearance and a little water is then permitted to cover the bottom. This is gradually increased as the *Oedogonium* develops.

The *Oedogonium* seems to thrive best upon a clean clay (kaolin). If the bottom is covered with a deposit of dark mud and in old ponds where a black, evil-smelling deposit has formed, it is scraped clean with

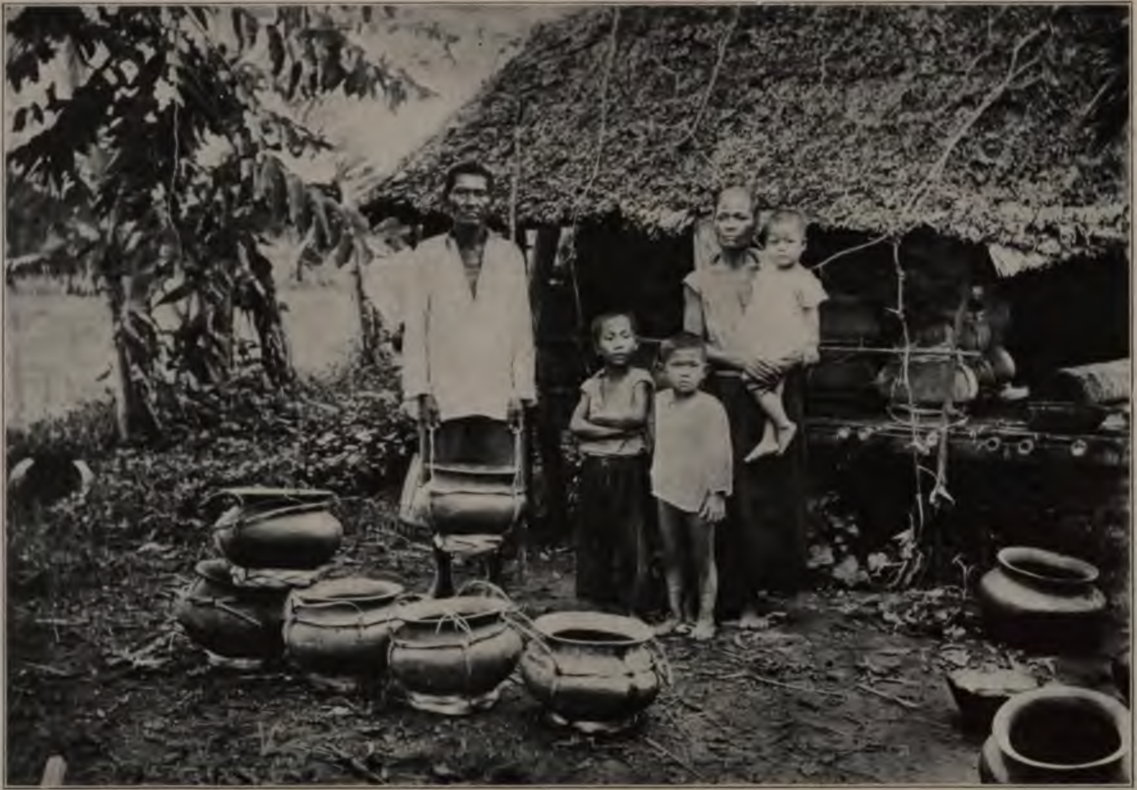

FIG. 1. THE GUARDIAN OF A FISH POND WITH HIS FAMILY, AND THE JARS OR PALYOK IN WHICH THE FRY ARE TRANSPORTED.

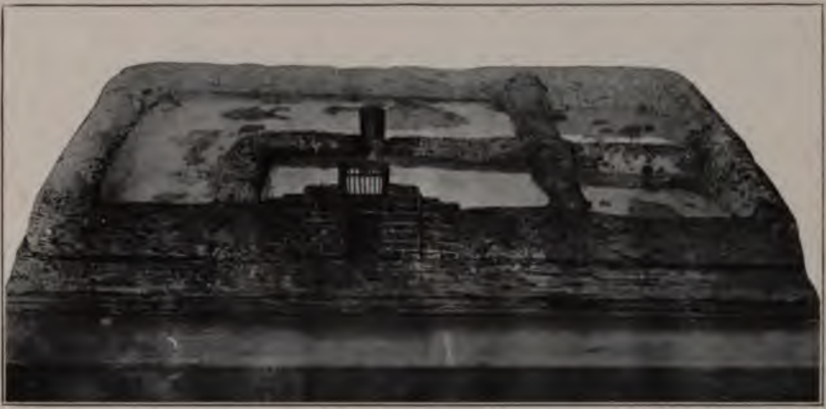

FIG. 2. MODEL OF A BAÑGOS POND SYSTEM CONSTRUCTED BY THE STUDENTS OF THE MALABON INTERMEDIATE SCHOOL.

a board. This operation is not necessarily done at any particular season, but whenever the condition demands it. The *Oedogonium* is sometimes purchased and placed in an exhausted pond. A small *banca* load is worth one peso.

A so-called "medicine" for the young fish (apparently used only in small ponds where the water is contaminated by close proximity to houses) is the *Lemna minor* Linn., the floating roots of which are greedily devoured.

When the fry are to be planted in the pond, the water is again allowed to drain off and the alga is partially killed by the hot sun. This, it is claimed, renders the *Oedogonium* soft and fragile for the tiny mouths. Eventually, the young *bañgos* are removed to the great pond where their quantity is largely governed by the supply of the food alga.

The average value of the ponds about Manila Bay is probably 40 centavos per square meter, giving a total of more than 6,000,000 pesos for the pond value alone, which I am convinced is a conservative estimate. I chose one pond which measured 140 by 170 meters as an average of the twenty or more shown on a surveyor's map compiled from data obtained from the owners of the properties.

METHODS OF FISHING.[3]

It has been my privilege to make personal observations of the methods employed in the fisheries of various parts of the world, in the United States, Alaska, New Zealand, Australia, Honolulu, and numerous Pacific Islands, also to some extent in Japan. Some time ago at the instance of the Secretary of the Interior, Mr. Dean C. Worcester and before I assumed my position in the Bureau of Science, I made a more detailed examination of the methods employed in the fisheries of the eastern United States in order to secure the latest information regarding the various kinds of nets and apparatus that could with profit be used to develop the commercial fisheries of the Philippine Islands.

It may not be out of place, therefore, to give brief descriptions of such apparatus as seems to me to be of especial value and short suggestions as to its use.

SEINES.

In the Atlantic fisheries a great many more fish are caught with the various kinds of seines than in any other way. In 1904, the New York fisheries alone captured by this method 214,099,725 pounds of fish, with a value of 826,597 dollars, United States currency.

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[3] A full description as to detailed method of construction, size of twine, mesh, hanging of net and methods of using can be obtained by applying to the United States Division of Fisheries.

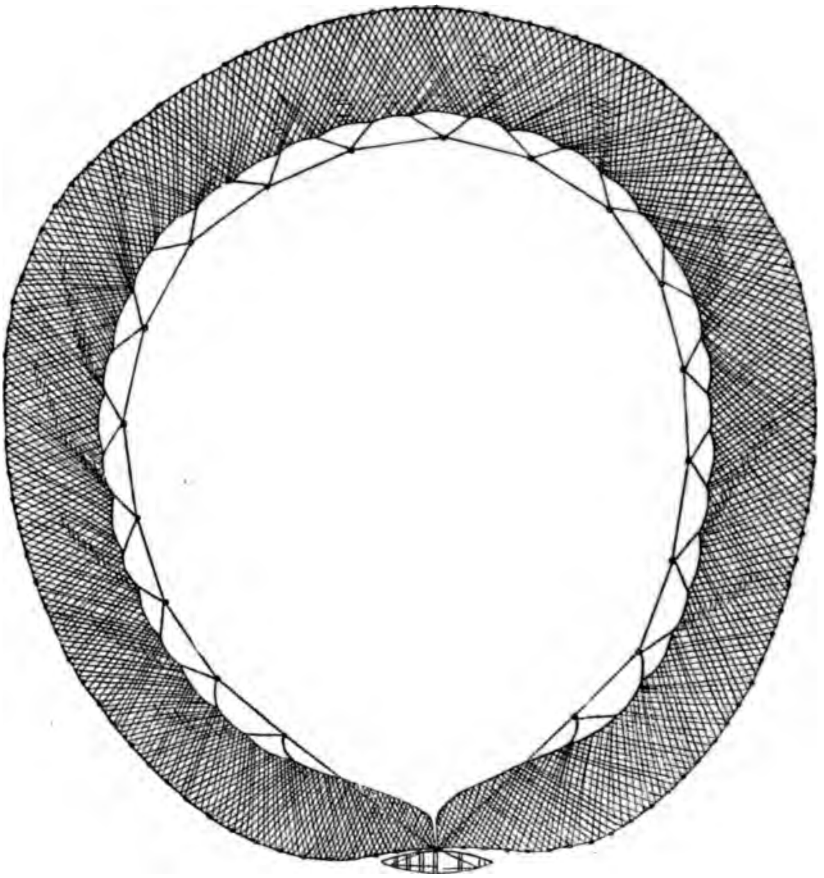

FIG. 3.—THE MACKEREL PURSE SEINE.

Purse seines (fig. 3).—One of the most effective nets used in the American fisheries is the purse seine. An ordinary, deep-water purse seine, such as is employed in the eastern mackerel fishing, is about 200 fathoms in length, and 20 to 25 fathoms in depth when it is hung, it being deeper in the center than at the extreme wings. The boat end of one wing is from 1 to 10 fathoms deep; the other end varies from 7 to 15 fathoms. It is made of three kinds of twine. The bailing-piece, which is a section of the net occupying about 10 to 12 fathoms along the center of the cork line and having about the same depth as length, is made of the stoutest twine. Beneath this, composing the remainder of the middle of the seine and extending to the bottom of the net, is a section knit of twine a size smaller. There is also a band of large twine, 15 meshes in depth, extending along the cork line of the seine on either side of the bailing-piece to the extremity of each wing. The remainder of the net is made of lighter twine. The lead and cork line are in the same position as in ordinary seines. This net is operated by a series of pursing ropes and rings, by means of which the bottom of the seine is drawn up and closed. Formerly this net was taken out in fishing schooners and when a shoal of fish was seen, it was placed in a seining boat, the shoal was surrounded by the net, the latter at once pursed, the vessel then brought alongside and the fish dipped out. Now, in some cases, the net is carried on a revolving table at the stern of a small steam-vessel or launch, and the surrounding of the shoal and pursing of the net is all done quickly and efficiently by steam. Frequently more fish are taken in this way than can be used in one day. In this event, they are put into a "spiller" or pocket, which is a form of live-box made of stout, coarse twine, and is attached to the side of the vessel, where it is kept in position by wooden poles or outriggers extending 15 feet from the vessel's side. This apparatus is nothing more than a big net bag 36 feet long, 15 feet wide, and 30 feet deep. This size will hold 200 barrels of live mackerel, but of course the spiller may be constructed of any dimensions. The purse net could probably be used with profit in catching the various kinds of mackerel (*masangui,* etc.) found in Philippine waters.

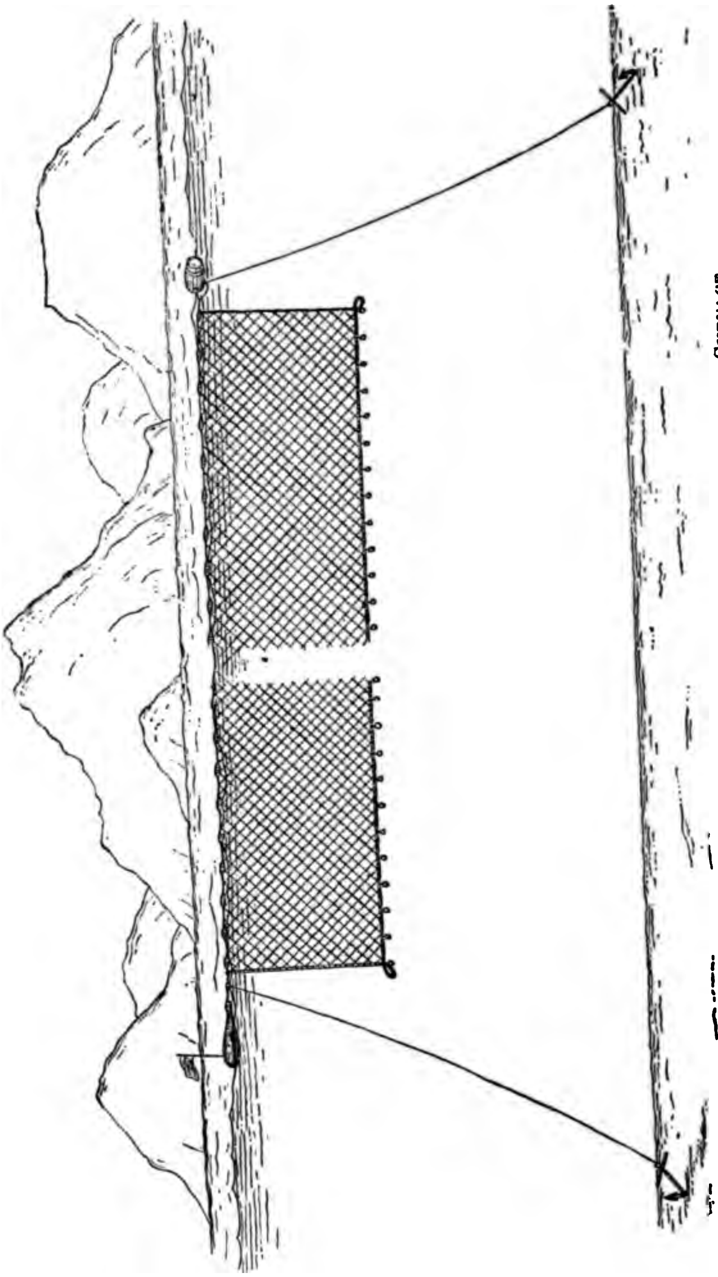

FIG. 4.—SHOWING METHOD OF SETTING GILL NETS AT THE SURFACE.

Gill nets (fig. 4).—The gill net is next in importance to the various kinds of seines. It is used chiefly in the herring fisheries, but in the Philippines large numbers of other kinds of fishes can profitably be taken by its means. This is especially true of the mullet, certain of the pompano, such as the *cassisung* [*Scomberoides toloo-parah* (Rüppell)], *atoloy* (*Caranx boöps* Cuv. et Val.), *mataan* (*Caranx freeri* Evermann et Seale), and such fish as the various kinds of snappers, for example the *bitilla* [*Lutianus fluviflamma* (Forskål)], *alangot* [*Lutianus lineatus* (Quoy et Gaimard)], and *pukit* [*Nemipterus nemurus* (Bleeker)]. These nets may be set either at the surface or at the bottom (see figs. 4 and 5), depending upon the kind of fish one wishes to catch. In the mullet fishery the nets are frequently allowed to drift with the current.

An ordinary herring net, 15 to 20 fathoms long and 2 to 3 fathoms deep, has a mesh varying from 2.25 to 2.75 inches. A herring vessel of the Atlantic fishery usually carries eight to fifteen of these nets with anchors and hangings. Off the coast of Palawan I have caught 120 fishes of good size in a single 20-fathom gill net in one night. So far as my experience goes this has been found the most successful net for use in the Philippines. The greatest drawback is the damage inflicted by sharks (fig. 5).

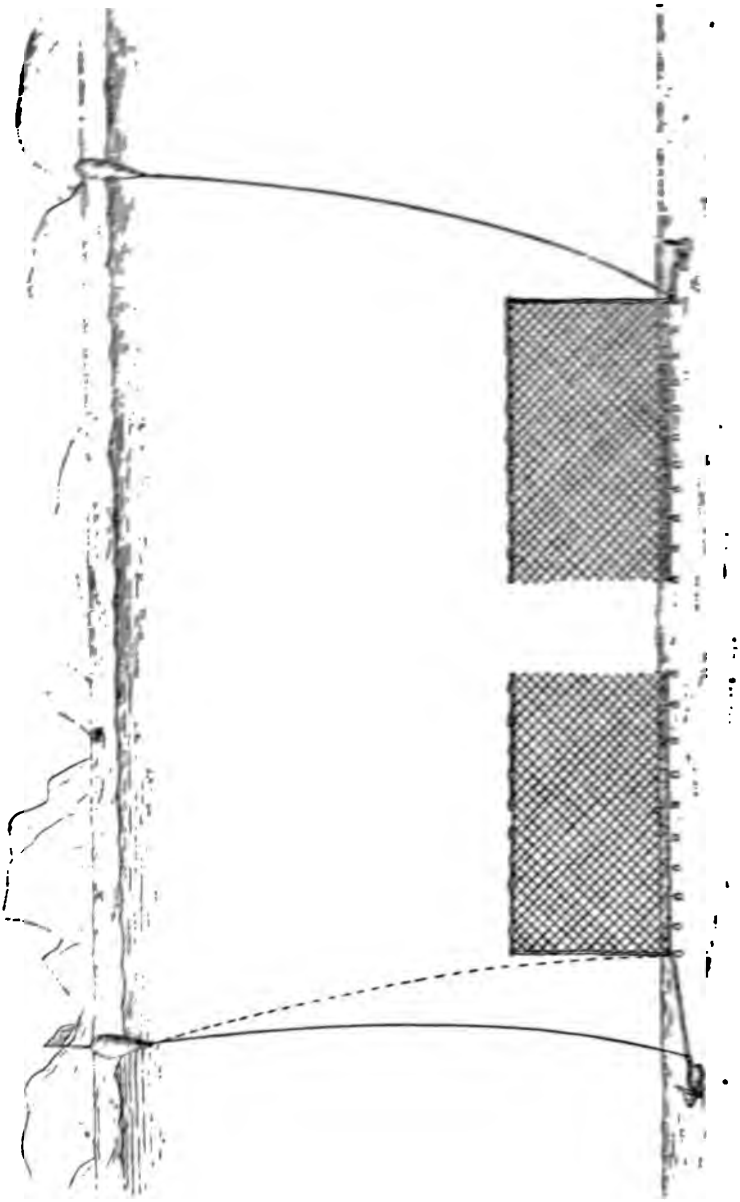

FIG. 6. SHOWING METHOD OF SETTING GILL NETS AT THE BOTTOM.

Paranzella, drag net.—San Francisco seems to be the only place in the United States where this form of net is used. The nets are from [illegible] drags the bottom [illegible] from 2 to [illegible] in width. [illegible] tug load of fish is secured at one haul. This net could only be used on smooth, sandy bottom free from coral, and employed chiefly to catch flatfish, flounders, etc.

Pound nets.—Many kinds of pound nets are used in the American fisheries, but as this manner of fishing is well known and used in the Philippines in the various forms of corrals or *baclods* no descriptions are necessary. Notwithstanding the expense of building, it is one of the most successful methods of fishing as is attested by the hundreds of corrals in the Islands.

Fyke nets.—These nets, which are usually of small size and consequently not very expensive, could be profitably used for the capture of the various species of catfishes, *dalags, martinicos,* etc.

OTHER METHODS OF FISHING.

Trawl lines.—While trawl-line fishing was formerly employed almost exclusively for catching codfish, it is now used to capture a great many varieties. At Monterey, California, I noticed the trawl lines being operated with good success to catch several kinds of fish, such as rock-cod, etc. They might be used with profit in the Philippines for such fish as the groupers (*Serranidæ*), the *mulmul,* and others which take the hook freely at the bottom. They are especially effective in taking eels.

The trawl line consists of a strong ground-line 300 fathoms in length, to which is fastened at intervals of one fathom a line 3 feet long to which a hook is attached. The hooks are baited and the ground-line anchored at the bottom with a buoy to indicate its location. A line for pulling it up is attached to it.

Live-cars.—Next to improving the method of catching the fish, the most important thing is to devise means by which they may be kept alive until they are wanted by the consumer. To this end the live-car is brought into requisition in several places, especially in tropical countries. This device is a very simple contrivance consisting of a square or quadrangular box constructed of slats placed close enough together to keep the fish in, but far enough apart to allow of a free circulation of water. The cars are immersed in the water and the fish are kept inside until they are wanted by the purchaser. At Key West the fishing schooners are now usually provided with wells in which the water is kept circulating, and in this way the fishermen are able to keep the fish alive. The fishing boats at Honolulu have wells with perforated sides through which the water circulates freely. At this place live-boxes or cars are in common use. Some of these are very large and are kept anchored close to the fish market. The purchaser selects his fish from the wharf, it is then dipped out of the live-box and delivered. Some modification of this plan could be adopted in the Philippines, but it is only feasible where the market is near salt water.

LOCATION OF FISHING BANKS.

The following fishing areas or banks seem to be the most prolific so far as I have investigated and they would well repay working.

The vicinity of Sitanki is practically all a fishing bank, being well supplied with organic life upon which fishes feed. The trade at this place is now in the hands of the Chinese. There are numerous good fishing banks in the vicinity of Zamboanga, especially off San Ramon and along the Basilan coast; one a few miles south of Cagayan Sulu and a number along the coast of Palawan. Some very prolific banks exist near the Cuyo Islands and close to Masbate and Cebu. The bank which chiefly supplies the Manila market is located near Corregidor Island.

Doubtless numerous other fishing banks can be found; in fact, wherever we encounter a comparatively shallow area of from 5 to 20 fathoms, with plenty of sea moss and rich in small marine organism, we may be assured of finding it well stocked with fishes. Sooner or later these places will all be accurately located and worked. What is needed is men of experience who will give the industry their entire attention; such people will win profitable results.

THE CHIEF FOOD FISHES IN PHILIPPINE WATERS.

Filipino.	Moro.	English.	Scientific.
Aguut		Grunts	*Sciænidæ*.
Aligasin		Mullet	*Mugilidæ*.
Alumahan, mataan	Salay salay	Pompano	*Scomber microlepidotus* Rüppell.
Ayuñgin	Lagohot	Grunt	*Pristipoma hasta* (Bloch).
Baga-baga	Bungu-bungu	Soldier fish	*Myripristis murdjan* (Forskål).
Bagaong, baraongan	Bigaong	Grunt	*Therapon jarbua* (Forskål).
Bakoko	Gaud-gaud	Porgy	*Sparus calamara* Russell.
Balang		Flying fish	Family *Erocœtidæ*.
Balila		Band fish	Family *Trichiuridæ*.
Banak, lumitog	Banak	Mullet	*Mugil cephalus* Linn.
Bañgos, banglot	Bangellus	Milkfish	*Chanos chanos* (Forskål).
Barangan	Tamban	Herring	*Ilisha hœvenii* (Bleeker).
Barikudo, babayo	Lambanak	Barracuda	*Sphyræna langsar* Bleeker.
Bia		Gobies	Family *Gobidæ*.
Bia, bunog	Tamangka	Goby	*Gnatholepis deltoides* (Seale).
Biang-itim	Tigbasbay	Goby	*Glossogobius biocellatus* (Cuv. et Val.).
Biang-puti, balla	Kapalo	Goby	*Glossogobius giuris* (Ham. Buch.).
Bidbid		Ten-pounder	*Elops saurus* Linnæus.
Bitilla, apahap, biquilla	Bahaba	Drum	*Umbrina russelli* Cuv. et Val.
Bonito, tangi	Sobad	Oceanic bonito	*Gymnosarda pelamis* (Linn.).
Buan buan		Tarpon	*Megalops cyprinoides* Broussonet.
Buguing		Half-beaks	Family *Exocœtidæ*.
Bañgayñgay, bunog	Tamanka	Goby	*Rhinogobius oxyurus* Jordan et Seale.
Butiteng sagarag		Puffers	*Spheroides lunaris* Bloch et Schn.

THE CHIEF FOOD FISHES IN PHILIPPINE WATERS—continued.

Filipino.	Moro.	English.	Scientific.
Butete	Tingga-tingga	Puffers	Family *Tetraodontidæ*.
Cabasi	Tatik	Bastard shad	*Anodontostoma chacunda* Ham.-Buc.
Dalag	Dalak	Mud fish	*Ophiocephalus striatus* Bloch.
Dangat, bagsang	Totok	Wharf fish	*Priopis urotænia* Bleeker.
Dilis, Monamon	Anakbat	Anchovy	*Anchovia commersoniana* (Lacépède).
Dumpilas	Tatik	Anchovy	*Anchovia dussumieri* Bleeker.
Espada		Band fish	Family *Trichiuridæ*.
Guno, ti-i	Guno'e	Silverside	*Atherina temmincki* (Bleeker).
Garropa		Grouper	Family *Serranidæ*.
Hasa-hasa		Japan mackerel	*Scomber japonicus* Houttuyn.
Hito, paltat		Catfish	*Clarias magur* (Ham.-Buc.).
Igat, quiuet	Taguibus	Rice-paddy eel	*Jenkinsiella nectura* Jordan.
Kabasi	Tatik	Basling shads	Family *Dorosomatidæ*.
Kabayo-kabayohan	Undok	Sea horse	Genus *Gasterotokeus*.
Kalaso, daldalag	Tigbasbay	Lizard fish	*Saurida argyrophaneus* Rich.
Kanduli kanduli	Gagu'e	Catfish	*Netuma nasuta* (Bleeker).
Kapalo, bunog	Kapalo	Goby	*Illana cacabet* Smith et Seale.
Kitang		Butter fish	Family *Ephippidæ*.
Lapo-lapo, garopa	Kukkut	Groupers	*Epinephelus merra* Bloch.
Lawin, bolador	Bengke	Flying fish	*Parexocœtus mento* (Cuv. et Val.).
Malakapas, icoran	Porok	Mojarritas	*Xystæma kapas* (Bleeker).
Mamali		Thread fin	Family *Polynemidæ*.
Martinico, araro	Piit	Climbing perch	*Anabas scandens* Daldorff.
Moong, mamong	Bengka	Cardinal fishes	*Amia chrysopoma* (Bleeker).
Mumul, molmol	Lammon	Wrasse-fishes	*Chœrops unimaculatus* Cartier.
Mulmul, Molmol	Ogos	Parrot fish	*Callyodon latifasciatus* Seale et Bean.
Pagui-, pagui	Kiampao	Sting ray	*Dasyatis kuhli* (Müller et Henle).
Pating, i-yo	Kaitan	Shark	*Scoliodon walbeehmii* (Bleeker).
Sakutin		Red fish	Family *Triacanthidæ*.
Samaral, malaga	Bel-long	Siganuo	*Siganus vermiculatus* Cuv. et Val.
Sapsap	Sapsap	Slip mouths	*Leognathus splendens* (Cuv.).
Saramullete, balaki	Mangentut	Goat fish	*Upeneus sulphureus* Cuv. et Val.
Silifiasi, bilis	Pinatay	Herring (young)	*Harengula* sp.
Siliu, siriu	Celo	Gar fish	*Tylosurus giganteus* (Temminck et Schlegel).
Sumbilang, ito	Baki'e	Catfish	*Plotosus anguillaris* (Bloch).
Sunog, uram-uram	Kamang	Flatheads	*Platycephalus insidiator* (Forskål).
Talakitok		Cavallas	Family *Carangidæ*.
Talakitok, tarakotokan	Anakbung	Cavallas	*Caranx sexfasciatus* Quoy et Gaimard.
Talang-talang, saleng-saleng.	Tangtang	Slipery dick	*Scomberoides toloo-parah* (Rüppell).
Tanguingue	Tangi	Spanish mackerel.	*Scomberomorus commersoni* Lacépède.
Tulis, tulisan	Tamban	Sardine	*Sardinella clupeoides* (Bleeker).
Tunsoy, Bilis	Tamban	Herring	*Harengula moluccensis* (Bleeker).

ILLUSTRATIONS.

PLATE I. Dilis, anchovy (Family *Engraulidæ*).
Anchovia commersoniana (Lacépède).
II. Siliñasi, herring (Family *Clupeidæ*).
Harengula moluccensis (Bleeker).
III. Gunoc, silverside (Family *Atherinidæ*).
Atherina forskalii Rüppell.
IV. Tanguingue, Spanish mackerel (Family *Scombridæ*).
Scomberomorus commersoni Lacépède.
V. Dalag, mud fish (Family *Ophicephalidæ*).
Ophiocephalus striatus Bloch.
VI. Mayamaya, red snapper (Family *Lutianidæ*).
Lutianus dodecacanthus Bleeker.
VII. Talakitok, pompano (Family *Carangidæ*).
Caranx speciosus Forskål.
VIII. Lapo-lapo, grouper (Family *Serranidæ*).
Epinephelus megachir (Richardson).
IX. Banak, mullet (Family *Mugilidæ*).
Mugil cephalus Cuvier.
X. Bañgos, milkfish (Family *Chanidæ*).
Chanos chanos Forskål.
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FIG. 1. (In text.) The guardian of a fish pond with his family, and the jars or *polyok* in which the fry are transported 520
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5. (In text.) Showing method of setting gill nets at the bottom 526

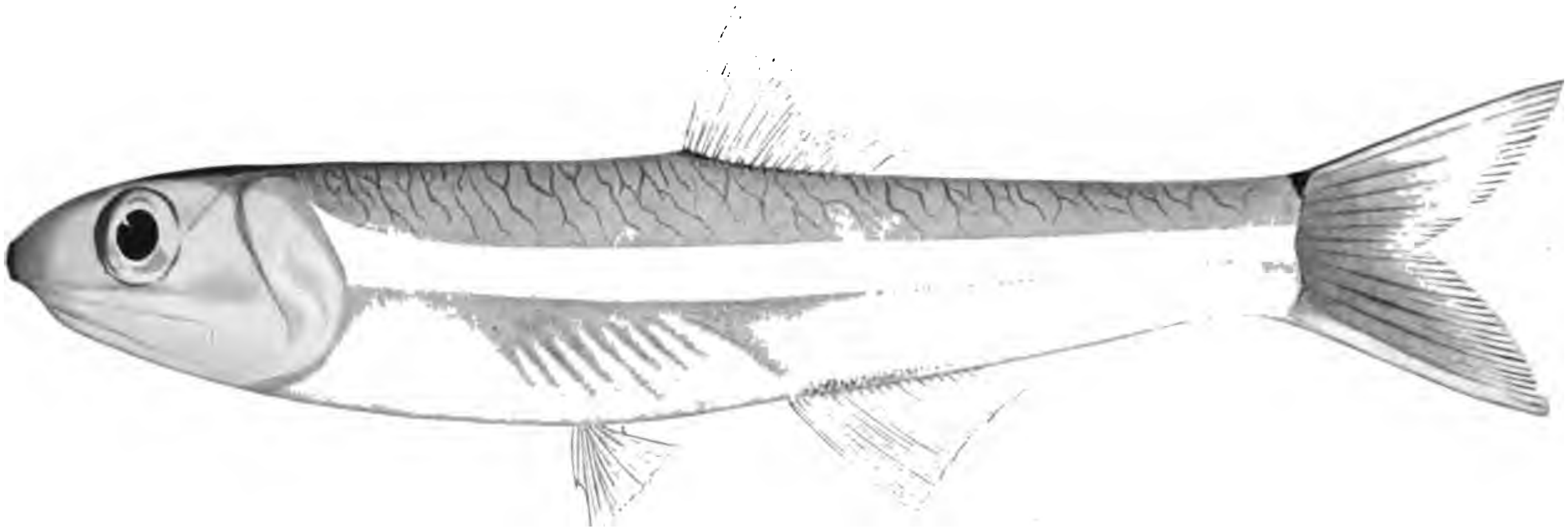


Plate I. DILIS, ANCHOVY.
Anchovia commersoniana (Lacépède).

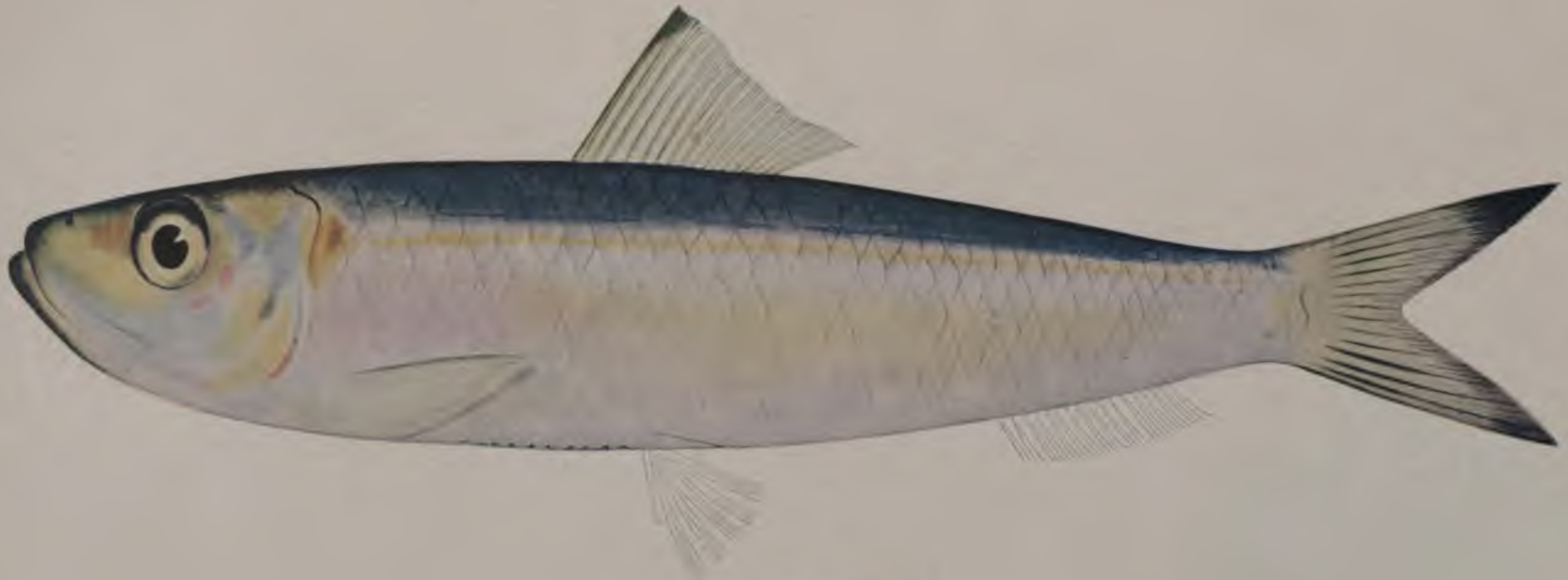


PLATE II. SILIÑIASI, HERRING.
Harengula moluccensis (Bleeker).

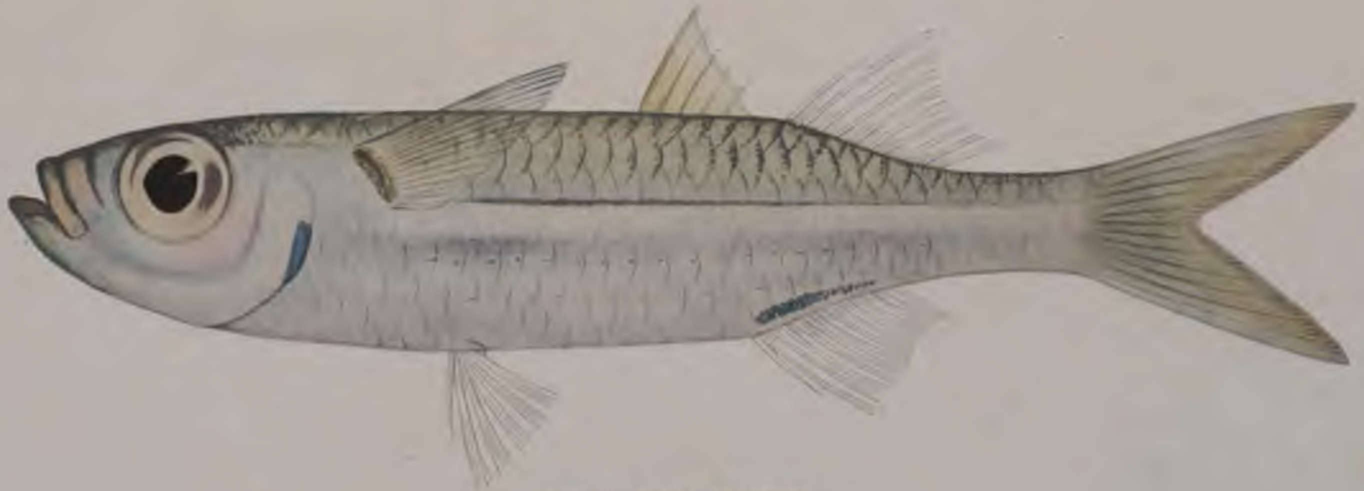


PLATE III. GUNOC, SILVERSIDE.

Atherina forskali: Ruppell.

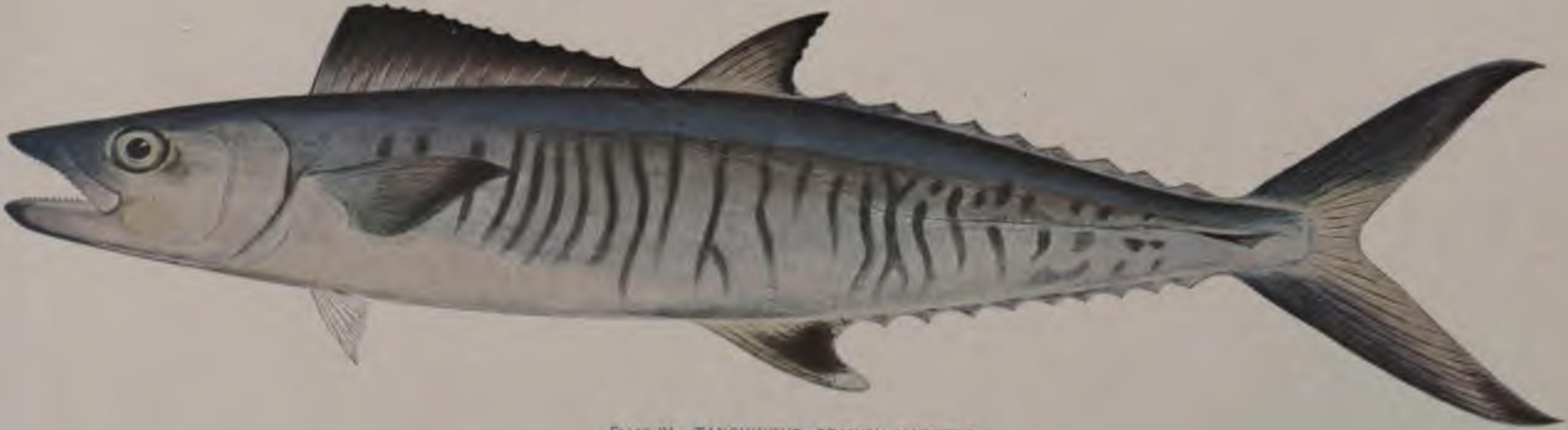


PLATE IV. TANGUINGUE, SPANISH MACKEREL.

Scomberomorus commersoni Lacêpêde.

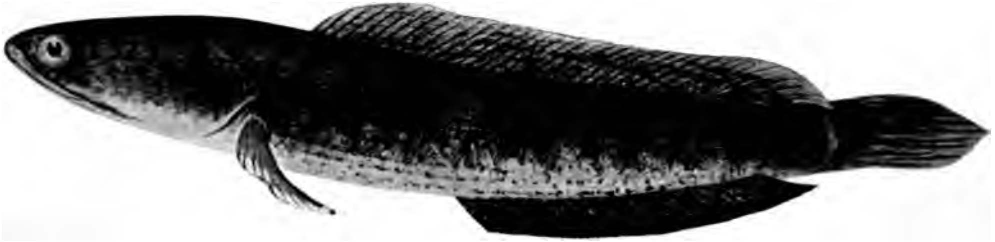


Plate V. DALAG, MUDFISH.

Family *Ophiocephalidæ*.

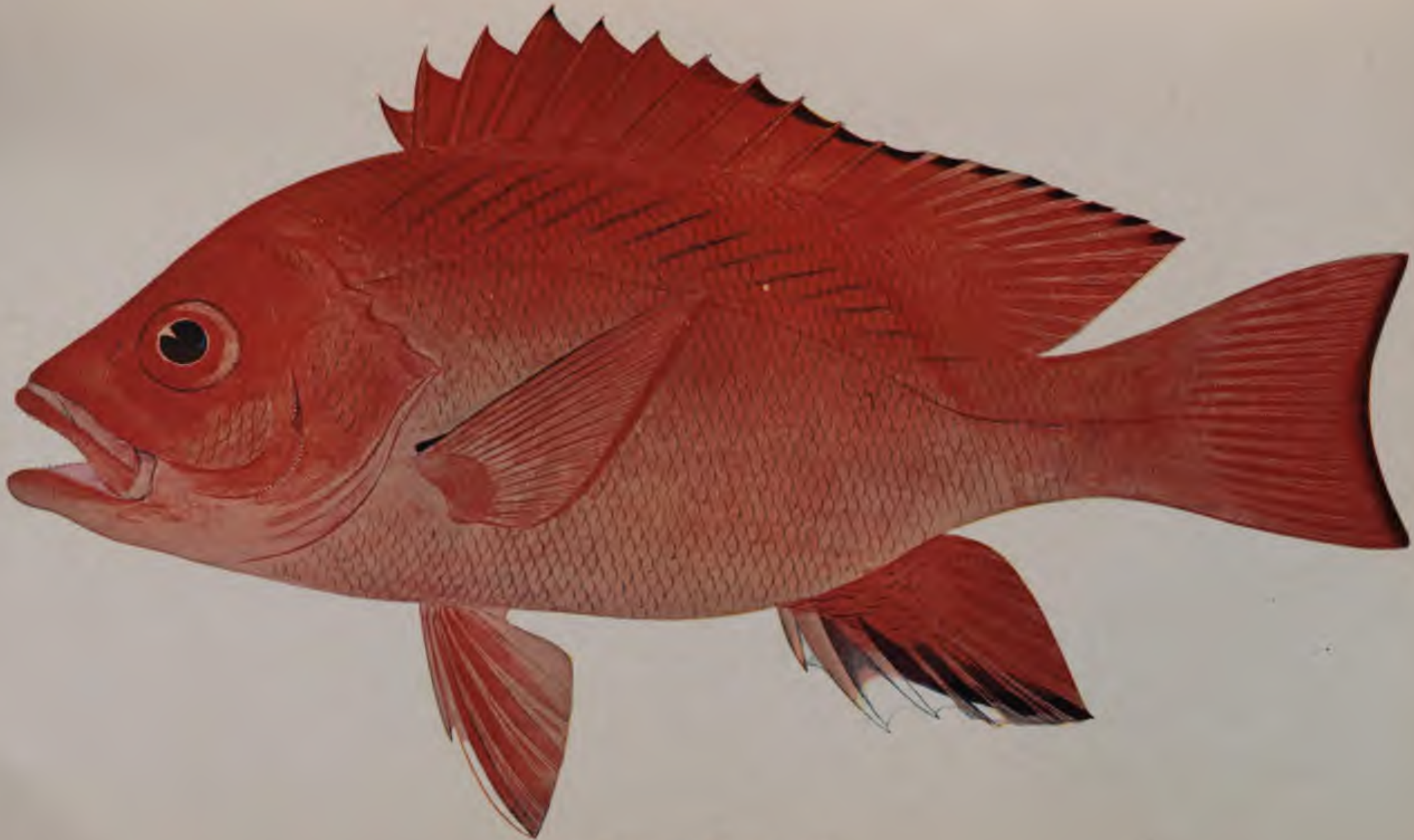


PLATE VI. MAYAMAYA, RED SNAPPER.

Lutianus dodecacanthus Bleeker.

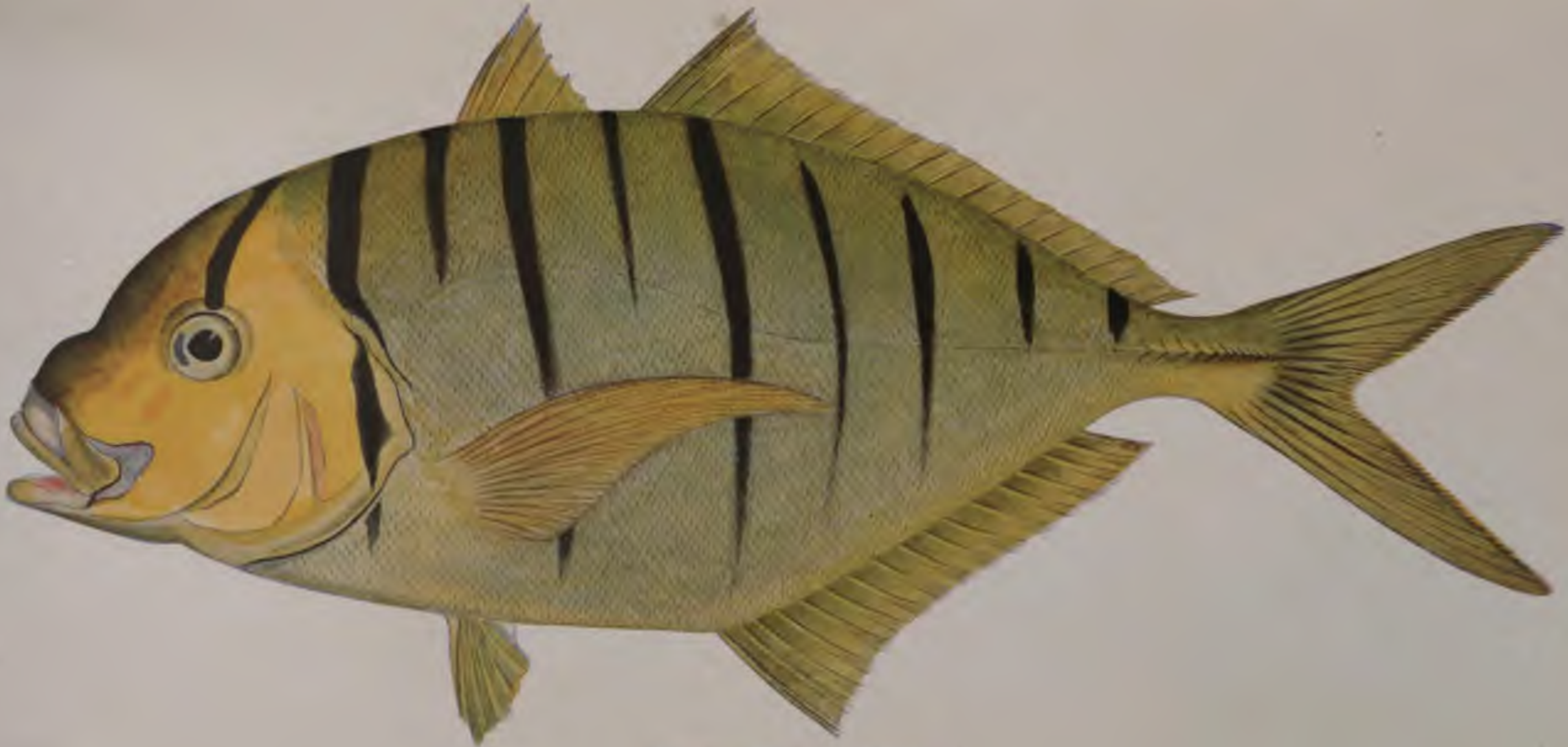


Plate VII. TALAKITOK, POMPANO.

Caranx speciosus Forskål.

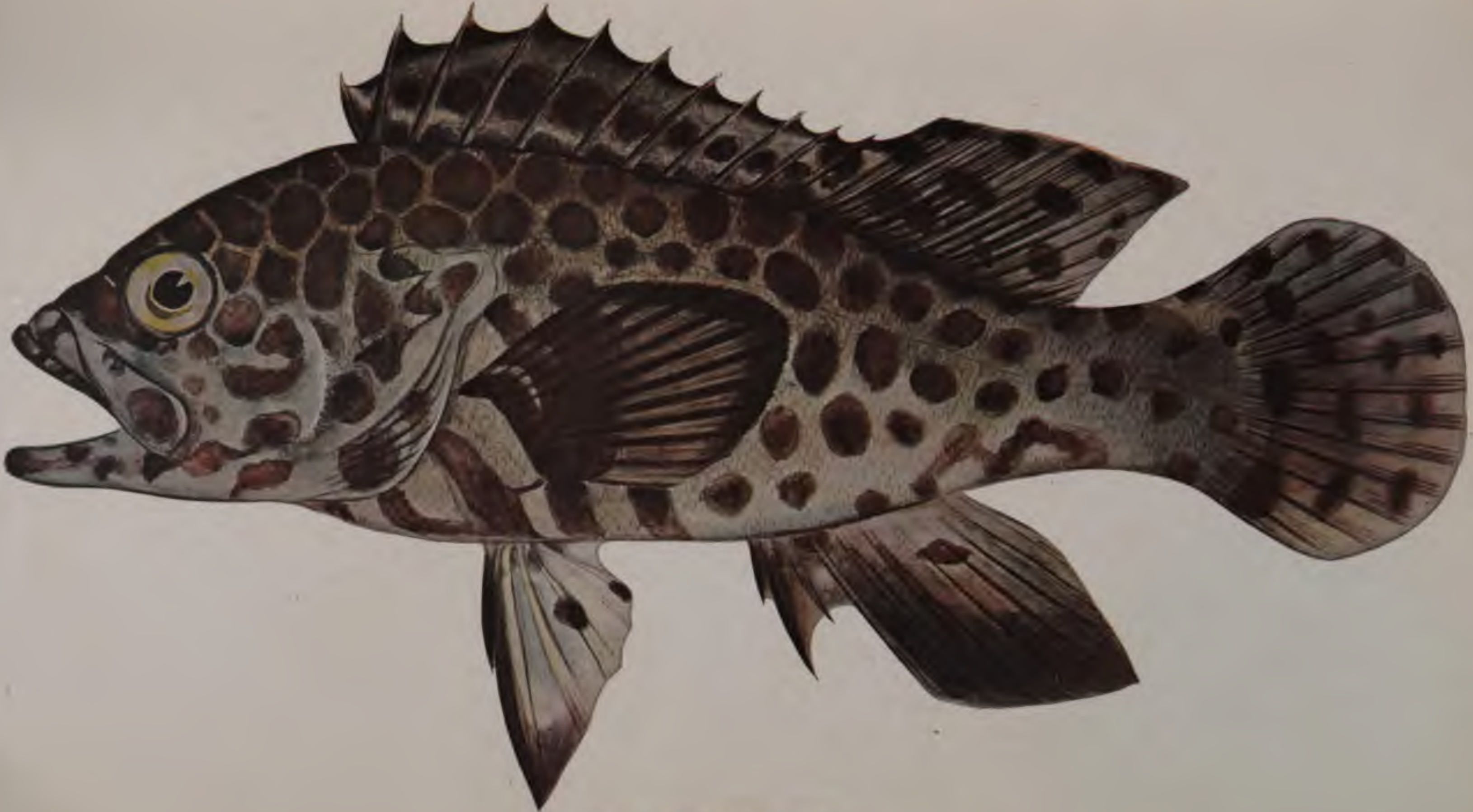


PLATE VIII. LAPO-LAPO, GROUPER.

Epinephelus megachir (Richardson).

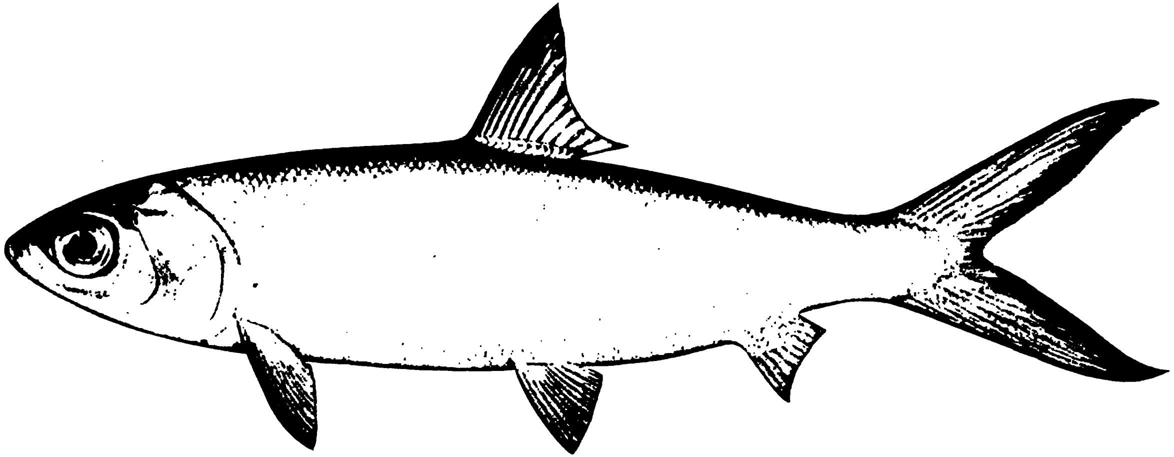


PLATE X. BAÑGOS, MILKFISH.

Chanos chanos Forskål.

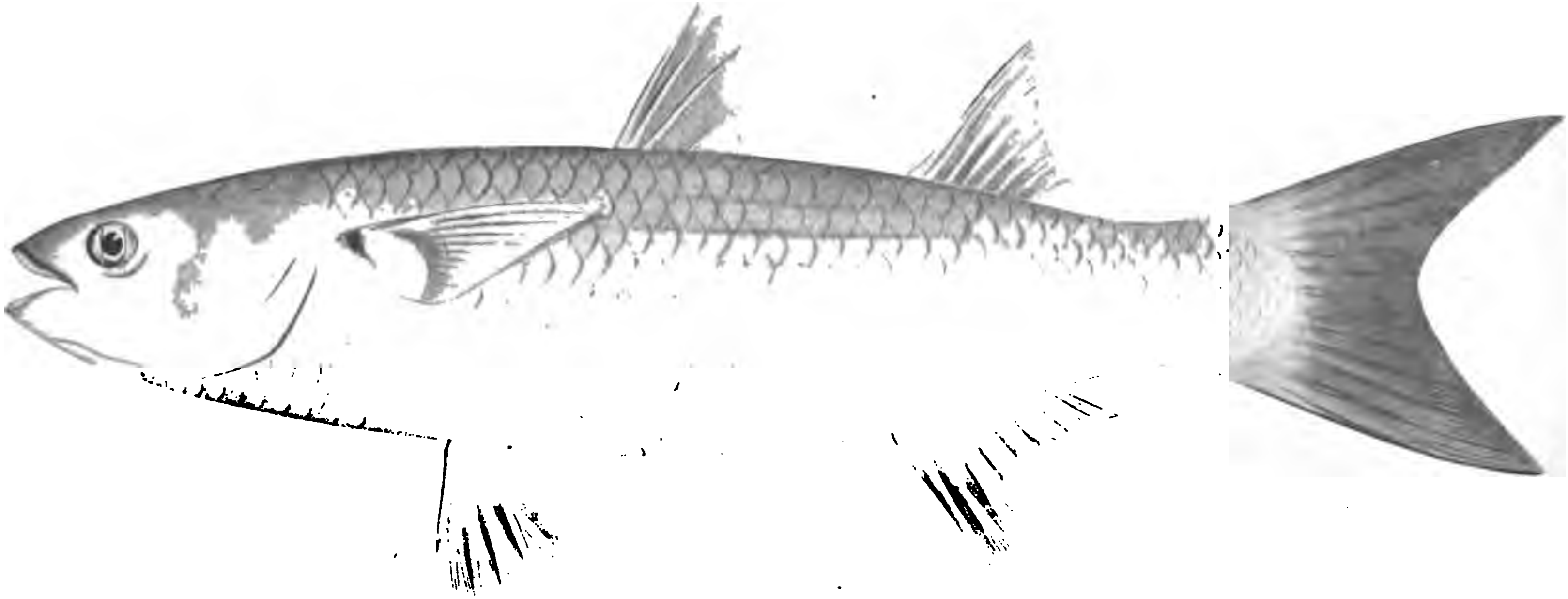


PLATE IX. BANAK, MULLET.
Mugil cephalus Cuvier

EDITORIAL.

TYPHOONS, COCONUTS, AND BEETLES.

Reports are frequently seen of the destruction of considerable numbers of coconut trees by typhoons. As the chief coconut-producing districts of the Philippines are subject to typhoons, and as the tree thrives in exposed situations, I have been interested in seeing what damage is actually done to it by storms. During several years of attention to this subject, I have yet to see the first sound trunk broken by the wind, or the first tree uprooted, unless its root system had already been exposed or weakened. Typhoons doubtless do break sound coconut trees; but it must be rarely indeed. Trunks extensively channeled by beetles are comparatively often broken; and trees the roots of which have been laid bare by washing away the soil, or which grow in ground too wet to permit the healthy growth of the roots, are often overturned. However, the loss of such trees is not a serious matter.

Very severe storms weaken the trees and set them back materially by breaking the leaves; and they sometimes destroy a considerable part of the crop in sight by throwing down immature nuts, even the very young ones, but vigorous trees entirely outgrow such injury within a year.

However, in places where beetles, especially coconut weevils (red beetles), *Rhynchophorus ferrugineus* Fabr., are a serious pest, violent storms furnish conditions for their entrance and multiplication and in this way do damage which is neither insignificant nor transient. This weevil is ordinarily unable to penetrate the thick and dense fibrous protection made by the imbricate leaf-bases around the upper end of the stem, and can only attack trees to which the rhinoceros beetle (*uang*), *Oryctes rhinoceros* Linn., has already done some injury. The breaking of the petioles, the tearing of the fibrous bases and the occasional split cracks of the trunks, caused by severe storms, make it possible for the weevils to enter many trees and so to multiply rapidly; once in the tree, this pest is decidedly more dangerous than the *uang*.

Mr. E. E. Green, government entomologist of Ceylon, reports a remarkable increase in the number of red beetles after a cyclone which visited the Batticaloa district in March, 1907. The beetles had been systematically collected since 1903, the number decreasing steadily; the record for various plantations being complete by months. In one case where 199 had been caught in May and June of 1906, 1,906 were captured in the same months of 1907. In another instance, the increase in the same months was from 138 in 1906 to 3,889 in 1907. This increase was almost entirely in the number of beetles extracted from the standing trees. Mr. Green says:

> "I have found nearly fully grown larvæ of the beetle (*Rhynchophorus*) in trees under conditions that indicate that they must have developed within a period of six weeks. It seems possible that the insect may reach maturity in from eight to ten weeks' time."

The only way in which such serious outbreaks, following typhoons, can be prevented, is by the suppression of the beetles at all times. This is impossible without such unity of action as is practicable only when demanded by law. As beetles are a pest throughout the Islands, legislation by the Insular Government is needed. The Provinces of La Laguna and Tayabas have passed ordinances against a local coconut pest, the bud rot, and have very promptly reduced it to comparative harmlessness, but single provinces can not deal effectively with beetles. The Straits Settlements, the Federated Malay States, and Ceylon have for years had laws aimed at the suppression of beetles, and their value is well proved. Coconut products are second only to abacá in the value of exports of the Philippines. The beetles are probably at this time our most dangerous and most destructive agricultural pest. It is hoped that the Legislature during its coming session will pass an Act providing for their suppression.

E. B. COPELAND.

CUTCH.

Cutch, a product of the heartwood of *Acacia catechu* Willd., has been known from India and Burma for many years. It is used as a dye and for tanning. Considerable quantities were exported to Europe for use in dyeing cotton goods. The supply was not entirely uniform or reliable because of the scattered manner of growth of the trees and the nomadic habits of the tribes that collected the cutch. When it was discovered that several of the different varieties of mangrove trees had bark which would furnish excellent dye and tanning material, they began to be considered as to the possibility of their furnishing a cutch to take the place of the Indian article.

It was found to be a comparatively simple matter to prepare the mangrove bark extract and the supply of mangroves was very great. Several companies started preparing the extract in the extensive swamps of Borneo; it succeeded in the market and quickly superseded the Indian cutch to such an extent that this term is now used mainly with reference to the mangrove extract.

When the use of aniline dyes became common, it was found that the Bismarck browns would furnish a cheaper and more easily handled dye than cutch; consequently, the latter gradually ceased to be used as a dye. It still had a very large field or usefulness as a tanning extract and the manufacturers felt very little concern at this loss of importance as a dye.

The original cutch was a low grade product and was admitted to the United States free of duty. The mangrove extract was of a better quality and it was decided to place a tariff on it. By Treasury Decision No. 27197, of March 9, 1906, it was declared that mangrove extract should no longer be allowed free entry as cutch, but should be dutiable under paragraph 22 of the Customs Act of 1897.

Cutch, as a crude and low grade extract, could not pay this duty and leave any profit for the manufacturer; consequently, the oldest of the firms in Borneo found it advisable to retire from business.. There are still four companies making cutch in Borneo, but they are shipping scarcely any of it to the United States because the duty takes away nearly all of the profits.

The principal species of mangroves from which the bark extract is made are *Rhizophora mucronata* Lamk., *R. conjugata* L., *Bruguiera gymnorrhiza* Lamk., *B. eriopetala* W. & A., and *Ceriops roxburghiana* Arn. Other species are also used; but these occur in the greatest quantity and are of the widest distribution. All of these are found in abundance in the Philippines.

F. W. FOXWORTHY.

COAL IN THE CAGAYAN VALLEY.

Coal has long been known to exist in the Cagayan Valley in the vicinity of Alcalá, and last September Mr. R. N. Clark and I, both of the division of mines, Bureau of Science, had the opportunity of visiting several of the outcrops.

The first was near Baggao, a small town about 10 kilometers up the Paret River, a stream joining the Cagayan at Alcalá. The coal outcrops in a small brook called the Wawing, about 3 kilometers north of the town. Here the seam is about a meter in thickness. Above the coal is a layer of clay gradually changing to a coarse sandstone; below is a sandy clay. This coal was worked for a short time during the Spanish régime and a large open-cut made, but after the death of the owner the concession was allowed to lapse.

About 2 kilometers west of this outcrop, coal occurs in the bed of a small stream flowing north. It was not possible to gauge the thickness of the seam here, but in all probability it is no greater than the first one we visited. There is said to be better coal farther up the Paret River in the San José Valley, near the barrio of Taytay, but the swollen condition of the river prevented a visit. Coal is also reported from the village of Temblique near Baggao, on the south side of the Paret.

The following description of coal outcrops in the vicinity of Nasiping is from the report of Mr. R. N. Clark:

"The village of Nasiping, a barrio of Gattaran, is situated on the northeast bank of the Cagayan River and about 2 kilometers above the junction of the Chico River. The town was formerly a municipality and in a rice-growing district. However, at present the rice fields are deserted and covered with a rank growth of cogon grass and guava bushes, all the inhabitants with the exception of a few families having migrated to the more profitable tobacco-raising districts. Those still living in this place are so poor that it is seldom possible to obtain from them provisions of any kind.

"To the northeast of Nasiping stretches a range of low, grass-covered hills among which the coal beds are located. The first bed visited lies N. 35° E. of Nasiping and 2.5 kilometers distant; the elevation by aneroid being 95 meters above the Cagayan River. This bed was on fire at the time of my visit, probably having caught from grass fires. It was burning at two places and also on the upper or north side, and an area oblong in shape and about 800 square meters in extent had already been consumed. The surface is barren, baked clay, lying 0.5 meter below the level of the surrounding, unburned area. The fumes arising from the burning coal are strong in sulphurous gas and some sulphur and alum occur mixed with the clay overlying the deposit. Old residents of Nasiping say that many years ago a large volcano existed in the nearby hills to the east. The story has been passed down for several generations, so the exact location of the reported volcano is not known. As no evidences of former volcanic activity were found in the region it is probable that this story has its origin in a former fire in the coal.

"The only other outcrop visited in this vicinity was exposed in the bed of a small estero 560 meters northwest of the burning bed. Several years ago a Mr. Anderson took out several tons of coal from near this outcrop. It was burned on the steamer *Chipaya*, but it is reported that it was found necessary to mix it with foreign coal to secure satisfactory results. At the time of my visit, these workings were caved in and overgrown with tall grass, so I was unable to observe the thickness of the seam or examine the adjacent rock formation. The outcrop in the nearby stream had a thickness of nearly a meter. No solid formation was encountered for a distance of 50 meters in the stream above this outcrop. There and above, alternating beds of shale and clay were found.

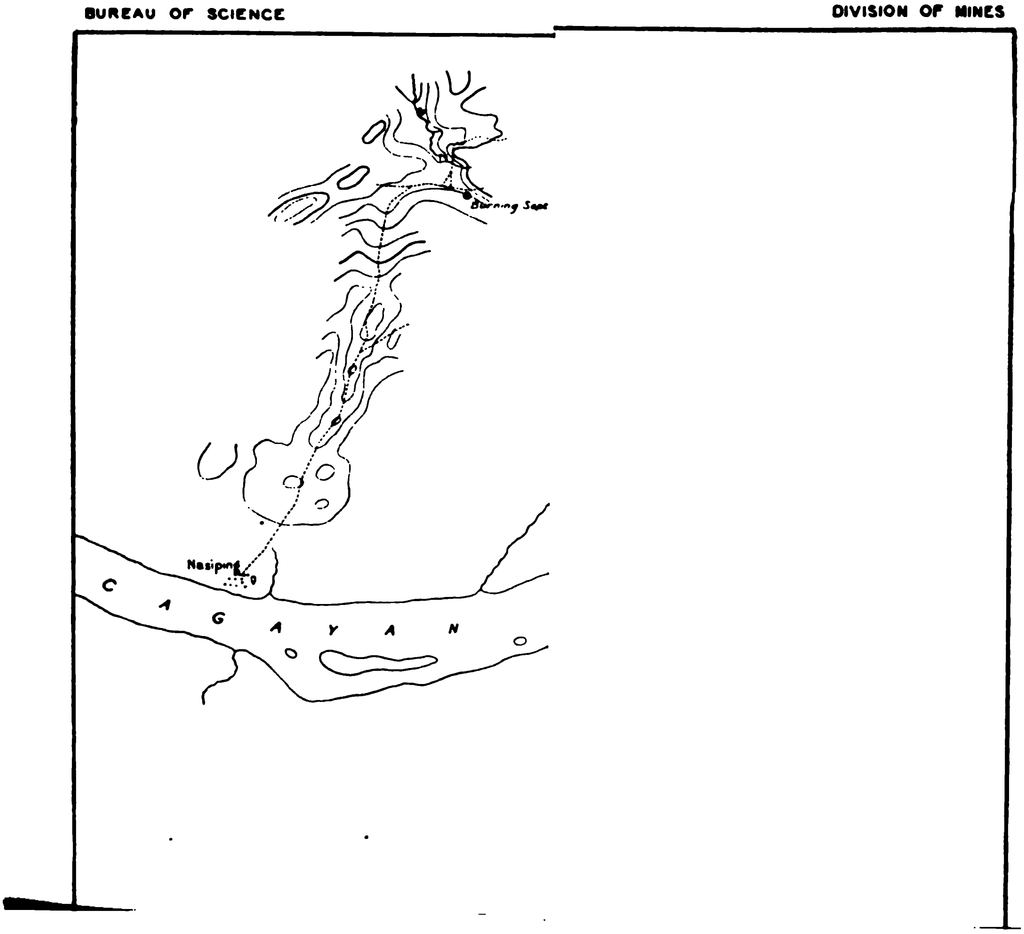
"Through the courtesy of Mr. H. J. Brown, I was able to secure a guide who took me to an outcrop 2.2 kilometers to the northeast of the steel bridge across the Tupong Creek and about 4 kilometers north of Alcalá. This outcrop was found in the bed of Taray Creek, barrio of Maasin, and 45 meters above the Cagayan River. The coal at this place strikes north-northeast and dips 30° to the west-northwest. Directly above is a layer of black clay and below a lighter colored variety. A coarse sandstone occurs 50 meters downstream. The coal seam is but 0.5 meter in thickness, and the natives say that an outcrop, only 15 centimeters thick was formerly exposed a kilometer to the south and on the south side of the main ridge."

The following analysis of this coal was made by Dr. A. J. Cox, of the Bureau of Science:

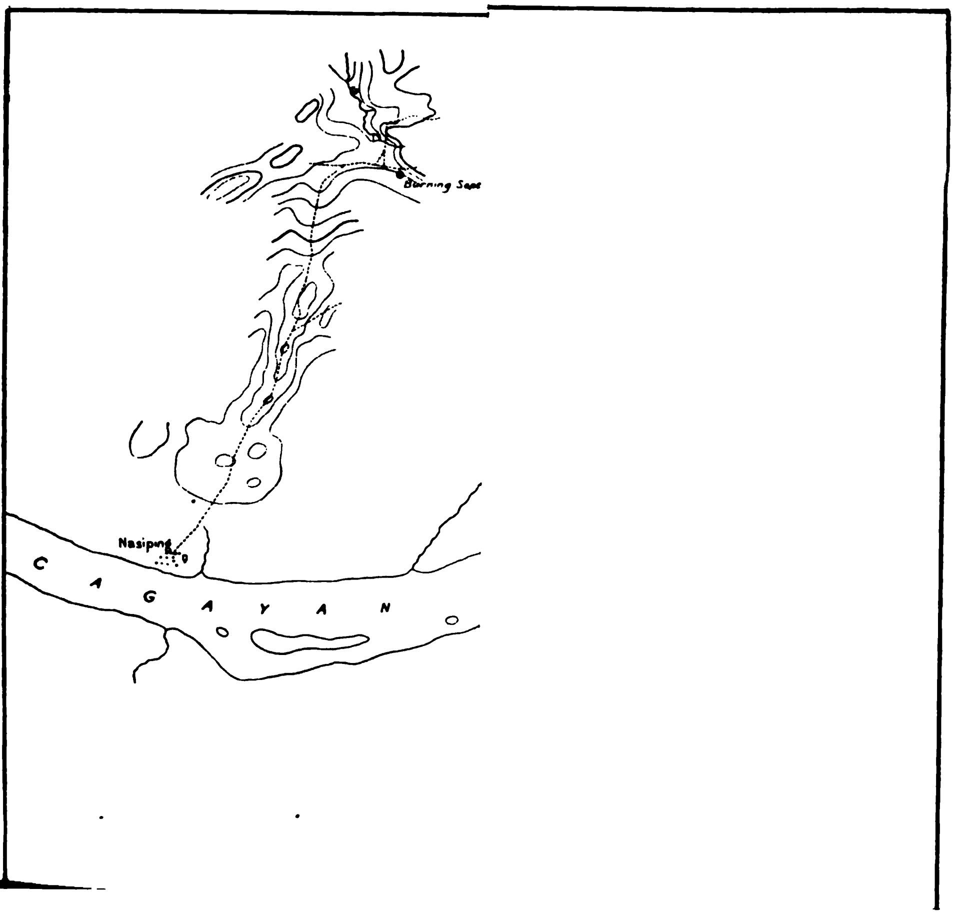
	Per cent.
Water	19.3
Volatile combustible matter	38.8
Fixed carbon	30.3
Ash	11.6
Total	100.0

The heating value of this coal is not such that it could be used with advantage alone for steam generation, but it must be remembered that the samples were taken from near the outcrops and that the coal probably improves somewhat as the bed goes deeper down. If we consider the poor quality of the coal and the thinness of the seams, together with the distance from Manila as well as the scarcity of labor, it will be seen that this coal probably will never become available for the Manila market. However, there is no reason why the river steamboats could not save a large part of their coal bills by using this material mixed with Australian, and it might be possible, if developments should show improvement in quality and continuity of seams, that steamers calling at Aparri would find it profitable to take part of their coal at that port instead of at Manila.

H. G. FERGUSON.


BUREAU OF SCIENCE
DIVISION OF MINES
Burning Seam
Nasiping
CAGAYAN

BUREAU OF SCIENCE DIVISION OF MINES



BOOK NOTICES.

General Physics: An Elementary Text-book for Colleges. By Henry Crew, Ph. D. Pp., xii+522. Price, $2.75 net. New York: The Macmillan Company, 1908.

The Elements of Physics. A College Text-Book. By Edward L. Nichols and William S. Franklin. In three volumes: Vol. II, Electricity and Magnetism. Cloth. Pp., viii+522. Price, $1.60 net. New York: The Macmillan Company, 1907.

ERRATA.

Page 41, **Diospyrus canomoi** should read **Diospyros canomoi A. DC.**

Page 42, **Antiaris toxicara** should read **Antiaris toxicaria Lesch.**

Page 44, **Sunasia Amori Blanco** should read **Lunasia amara Blanco.**

Page 70, Table II, No. 22, **0.827** should read **0.927.**

Page 86, Under substances used for synthesis of ylang-ylang oil, add **linaloöl** and **geraniol.**

Page 146, Table VII, Calcium oxide should read **61.94%** from bag; **62.04%** from can instead of **63.44%** and **63.32%.**

Page 250, Under Filaria mosquito, **arribalzaga** should read **Arribalzaga.**

Page 405, **Volcanic fuel** should read **volcanic tuff.**

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